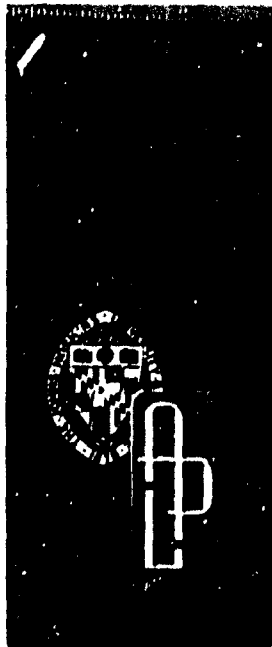TG—864
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Technical Memorandum

AIRCRAFT TRACTOR ROCKET-ESCAPE SYSTEM– SIX-DEGREE-OF-FREEDOM DIGITAL SIMULATION
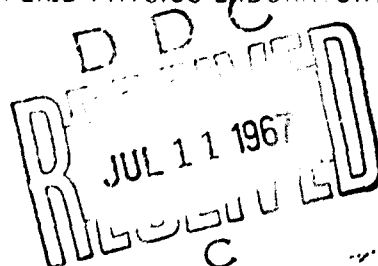
Final Report

by FRANK BADER and DEAN R. COLEMAN

THE JOHNS HOPKINS UNIVERSITY ■ APPLILD PHYSICS LABORATORY

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AIRCRAFT TRACTOR ROCKET-ESCAPE SYSTEM— SIX-DEGREE-OF-FREEDOM DIGITAL SIMULATION Final Report

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ABSTRACT

This report presents a six-degree-of-freedom digital simulation of an aircraft tractor-rocket air crew escape system. The simulation described herein is a six-degree-of-freedom simulation in that each of the objects considered is free to translate linearly in three directions and rotate about these three linear axes. The simulation considers the motions of the four "objects" comprising the escape system: the airplane, the tractor rocket, the towline, and the crewman. The simulation begins at the instant the tractor rocket has been ejected from its catapult and terminates when the tractor rocket has burned out.

Previous simulations studied at the Applied Physics Laboratory were two-dimensional, three-degree-of-freedom digital simulations. These simulations did not reproduce the effects of aircraft out-of-control motions.

The tractor rocket escape system was conceived by the Stanley Aircraft Corporation for military aircraft which currently have no ejection systems for the air crew.

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I. SUMMARY

The Naval Air Systems Command authorized the Applied Physics Laboratory (Ref. 1) to perform a six-degree-of-freedom digital computer simulation analysis of the Stanley Aviation Corporation's "Yankee" tractor rocket aircrew escape system, see Fig. 1.[*] Because this escape system proposes to extract crewmen from out-of-control (spinning) aircraft, NAVAIRSYSCOM further requested, via Ref. 1 , that APL use aircraft spin data from Ref. 2 in its studies. Twenty five specific sample intervals were specified by the Naval Air Systems Command from this data for evaluation through a computer analysis.

The ejection simulation study for 23 of these flight conditions has been completed. NATC data in Ref. 2 were incomplete for two of the runs (aircraft pitch angle missing), so these were omitted from the analysis. The aircraft flight conditions for the 23 data samples are summarized in Figs. 2 through 9. The simulation results are shown in Figs. 10 through 33. Each of these figures shows five plot systems which collectively indicate the following quantities for each simulated ejection.

1. The crewman's and rocket's ejection trajectory with respect to a coordinate system attached to the maneuvering aircraft.

2. The magnitude and direction of the forces exerted upon the crewman during ejection, relative to a coordinate system moving/rotating with him.

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[*]All illustrations may be found in the back of this report beginning on page 21.

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In eight additional runs, the rocket catapult angle was 63° instead of 77° (corresponding to an earlier Stanley design); simulation results for these runs appear in Fig. 33 through 40. These illustrations graphically represent APL simulation findings for flight conditions originally specified by the NAVAIRSYSCOM task, and additionally, eight runs that duplicate aircraft maneuvers of eight of those specified, but use a changed value for one parameter in the ejection system; namely the tractor rocket launch angle. As will be seen later, this duplication affords a valuable basis for comparison of ejection system constants, suggesting an optimal compromise for angle for rocket launch.

In general, the simulation study showed that the tractor rocket escape system could successfully remove a crewman from a maneuvering aircraft provided aircraft roll/pitch rates were not excessive (i. e., were below 100°/second).

The 67° rocket launch angle produced more ejection failures than the 77° value since it augmented the angle of pull between the tractor rocket and the crewman in the rolling airplane.

II. INTRODUCTION

The Stanley Aviation Corporation has proposed the use of a
tractor rocket operated aircrew escape system called "Yankee" for re-
moval of aircrewmen faced with the need for bailout. This system ap-
pears to have certain advantages and limitations different from the
aircraft ejection seats currently in use.

The tractor rocket escape system conceived by Stanley Aviation
provides for the extraction of a crewman from an aircraft according to
the following sequence, most simply pictured (see Fig. 1) for a non-
maneuvering aircraft flying at a slow speed.

1. A rocket located under the aircraft canopy aft and above
    the cockpit is catapulted from the aircraft at a preset
    attitude.

2. The rocket deploys a 10-foot towline whose other end is
    attached to the crewman's parachute harness. The rocket
    ignites when the entire length of the towline has been de-
    ployed and for 0.5 second thereafter exerts a 2000-pound
    pull upon the crewman in a roughly vertical direction,
    (along his longitudinal axes). This pull will extract him
    from the cockpit about 0.2 second from rocket ignition
    time, and impart to him a maximum upward speed over
    100 ft/sec. The coupled system of rocket-towline-crewman
    tends to align itself in a straight line as it departs from the
    aircraft.

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Ejection dynamics become more complex in direct proportion to the complexity of the aircraft motion. Linear and rotational aircraft motion can compromise the crewman's safe extraction through either of these two mechanisms:

1. From aerodynamic drag upon the components of the ejection system (rocket-rope-crewman) which increase with augmentation of the aircraft forward speed, tending to carry the rocket aft of the cockpit during the 1/3-second time interval required for rocket deployment and crewman extraction. This, in turn, will produce a rearward trajectory for the escaping crewman.

2. From aircraft rotation during the time interval from catapulting of the tractor rocket to the instant of emergence of the crewman. Such rotation causes an increase in the angle of misalignment of pull upon the crewman equal to the aircraft rotation during this time interval.

Both of these effects may occur in random combinations, particularly when the aircraft is out of control. The first, flight speed, has a more systematic effect than the latter, and may be partially mitigated by adjusting the rocket launch angle more forward of vertical for ejection at higher aircraft speeds. (For aircraft speeds up to 340 knots, a single fixed forward "tilt" angle around 15' may suffice.) The second of these effects, aircraft rotation, presents major difficulties for any approach at compensation. Theoretically, a variable-angle rocket launcher, servo controlled from roll/pitch rates, might effect such a compensation, but only at the price of excessive system complexity.

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III. DESCRIPTION OF THE SIMULATION

The simulation described here is a six-degree-of-freedom simulation in that each of the objects considered is free to translate linearly in three directions and rotate about these three linear axes. The simulation considers the motions of the four "objects" comprising the escape system: the airplane, the tractor rocket, the towline, and the crewman. The simulation begins at the instant the tractor rocket has been ejected from its catapult and terminates when the tractor rocket has burned out (or the crewman can be "coasted" up to maximum altitude). Subsequent parachute deployment is not simulated.

The simulation problem proper is solved principally in an earth-bound rectangular coordinate system where the aircraft is initially positioned at a specified altitude above the origin. The aircraft possesses an arbitrary velocity along each coordinate axis and an arbitrary pitch/yaw/roll attitude. Subsequent aircraft motion is derived by entering linear acceleration and angular velocity data into the calculation at each 0.1-second time increment and then employing these values as constants during the succeeding 0.1-second interval. Linear accelerations and velocities are integrated to produce positions; the aircraft attitude is determined by space projection, after rotation, of a set of unit vectors affixed to the aircraft.

The rocket trajectory is found by computing towline, aerodynamic, and gravity forces and their moments upon it, deriving its linear and angular accelerations through Newton's laws of motion, and integrating

accelerations into velocities and position. The rocket angular accelerations
are derived in a rocket-based coordinate system in order to cope with the
asymmetry of the rocket's moments of inertia. The rocket space attitude
is found through rotation of a set of unit vectors in the rocket system, which
is then projected on the ground plane.

As a distributed system, the towline is treated in an approximate
fashion. In principle, since the forces exerted on the towline by wind drag
are distributed along its length, the line will possess a curve along its
length. The stretched length of the line, and hence its tension, are then a
function of both the distance between its ends (tie points to rocket and
crewman) and the wind deflection. Typically, the towline tension force
caused by rocket pull is around 2000 pounds, and is very large compared to
crosswind forces; therefore, in this simulation, the simplification is made
that the towline forces are computed as if the line were straight between its
two ends. These forces are a longitudinal force (along the line joining the
two ends of the line) proportional linearly to the stretch in line length and
a wind force perpendicular to the line and in the direction of the crosswind.
The tension force and half of the cross-wind force are applied to man and
to the rocket.

The crewman is treated as a rigid body of rectangular form pos-
sessing three mutually perpendicular drag areas and three given moments
of inertia. The crewman's motion is confined to the seat back track axis
until he emerges from the aircraft. Applied forces are resolved perpen-
dicular and parallel to this axis. Perpendicular ones are assumed to
create a proportional frictional force which is subtracted from the tangent

force. Using these forces, the crewman's space acceleration is computed along the seat back axis and used to compute his acceleration relative to the aircraft. During this period the crewman's attitude is constrained to remain fixed with respect to the aircraft and its rotation. The crewman's location with respect to the aircraft is then secured by (double) integration of his relative acceleration. After the crewman has traveled far enough to emerge from the aircraft, the aircraft constraints are removed and his body, initially oriented along the seat back axis and rotating with it, is now free to rotate and translate in six degrees of freedom. The crewman's subsequent linear and angular accelerations are computed from the subsequent linear and angular accelerations are computed from the applied forces (aerodynamic, line, and gravity) and their moments. The crewman is assumed to remain rigid and to be symmetrical with respect to aerodynamic forces. The crewman's position and attitude are then computed in a manner analogous to that described in connection with the rocket. No tip-off torques are applied to the crewman as he emerges from the aircraft. A proper representation of these torques would require description of the crewman's body as a jointed elastic system and would require specific definition of the cockpit enclosure that originally contains him.

Once free of the aircraft, the rocket, towline, and crewman are followed as a coupled system until burnout of the tractor rocket, ignoring the aircraft. At rocket burnout, the crewman's trajectory and position are coasted with only gravity and aerodynamic forces acting. The calculation is terminated when the crewman reaches the peak altitude of his trajectory.

IV. PARAMETERS CHARACTERIZING SYSTEM

Airplane

The airplane is characterized by its position in a rectangular coordinate system in space. The origin of this coordinate system is located beneath the crewman's position in the aircraft at zero time.

PA1   the aircraft distance north of the origin

PA2   the aircraft altitude above the origin

PA3   the aircraft position east of the origin

DPA1   aircraft velocity north (ft/sec)

DPA2   aircraft velocity upward (ft/sec)

DPA3   aircraft velocity east (ft/sec)

DVA1   aircraft acceleration forward (ft/sec) ⎫

DVA2   aircraft acceleration upward (ft/sec) ⎬ in aircraft coordinates

DVA3   aircraft acceleration forward (ft/sec) ⎭

THAV   aircraft attitude angle above horizontal

THAB   aircraft attitude angle east of north

THAR   aircraft roll angle to right of vertical

WA1   aircraft roll rate ⎫

WA2   aircraft yaw rate ⎬ in aircraft coordinates

WA3   aircraft pitch rate ⎭

Initial values for aircraft position, PA2, PA3, velocity DPA1-3, attitude angles THAV, THAB, and THAR are taken from Patuxent Naval Air Test Center flight test data and entered into the simulation. Successive aircraft positions are generated through read-in of aircraft linear acceleration and angular velocity data. These are used to increment the aircraft

velocity/position and to rotate the aircraft coordinate system to reproduce in the simulation the actual aircraft motions described in the Patuxent NATC test report.

Ejection Seat Parameters

GAMM	the seat back track angle guiding crewman's exit from aircraft
THARV	the rocket launcher elevation angle
THARB	the rocket launcher bearing angle
HTSTR	height of aircraft fuselage structure above crewman's center of mass seated in cockpit
CFR1C	coefficient of friction of crewman's seat on track
DR(1)	rocket position in aircraft, fore/aft of crewman
DR(2)	rocket position in aircraft, above crewman
VRL	launch velocity of rocket catapult (ft/sec)
WRO	rocket spin rate
XLM1	distance forward from crewman's CG to towline harness
XLM2	distance up from crewman's CG to towling harness
XLR	distance from rocket CG to towline tie point

Rocket Characteristics

TBR	duration of rocket burning (seconds)
TDB	time of rocket ignition delay from towline deployment (seconds)
TRF	time of rocket launch to rocket ignition if time ignition is used (seconds)
TTB	time constant of rocket thrust build up (seconds)
TTD	time constant of rocket thrust delay (seconds)
WTR	mass of rocket initially (slugs)

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DWTR	rate of burning of rocket propellant (slugs/sec)
$\left.\begin{array}{l} \text{XJR1} \\ \text{XJR2} \\ \text{XJR3} \end{array}\right\}$	rocket moments of inertia about principal axes
lJTMAX	maximum rocket thrust (pounds)
$\left.\begin{array}{l} \text{ACDR1} \\ \text{ACDR2} \\ \text{ACDR3} \end{array}\right\}$	rocket drag areas
RL	rocket length

Towline Characteristics

TL	length of towline (feet)
DROPE	effective line diameter
WROPE	mass of line
CROPE	drag coefficient of line
TBYO	initial payout drag on line
TBYD	rate of increase of rope payout force with line length extended
TKL	elastic rope force stretch constant of line (pounds force/foot stretch)
TVL	rope internal friction damping coefficient (pounds force/foot/sec stretch rate

Crewman Characteristics

WTM	mass of crewman, with equipment
$\left.\begin{array}{l} \text{XJM1} \\ \text{XJM2} \\ \text{XJM3} \end{array}\right\}$	man's moment of inertia about three principal body axes

ACDM1
ACDM2   man's aero drag areas about three principal axes
ACDM3

HMH   distance man's center of mass to head

HMF   distance man's center of mass to feet

HMA   distance from man's center of mass to center of aerodynamic pressure

V.   RESULTS PROVIDED BY THE SIMULATION

The digital computer program provides as outputs the following quantities.

T	time in ejection cycle
PA1 PA2 PA3	aircraft space position north, above the east of origin
DPA1 DPA2 DPA3	aircraft speed in space north, upward and eastward
THAV	aircraft pitch attitude
THAB	aircraft heading
THAR	aircraft bank angle
WA1 WA2 WA3	aircraft axis forward, up, and right
TL	towline length
PR1 PR2 PR3	tractor rocket position same inertial (earthbound) coordinate system as for airplane
DPR1 DPR2 DPR3	tractor rocket velocity, coordinates as above
THRV	rocket attitude angle
THRB	rocket heading angle

WR1
WR2 tractor rocket angular velocity about three fixed inertial axes
WR3

PM1
PM2 crewman's space position, same inertial (earthbound) coordinate
     system as for airplane
PM3

DPM1
DPM2 crewman's space velocity, same inertial coordinates as position
DPM3

WM1
WM2 crewman's angular velocity about earth located inertial axes
WM3

AMA1 crewman's position with respect to aircraft, first coordinate is
      forward along fuselage, second up in respect to cockpit, and the
AMA2 third out along the right aircraft wing; this coordinate system is
AMA3 affixed to the aircraft and rotates/translates with it.

GMM1 accelerations applied to the crewman, g's (applied force divided
      by crewman's weight) along crewman's three axes; first axis is
GMM2 forward of crewman, second is foot-to-head, and third is along
GMM3 crewman's left-right; this coordinate system rotates with the man

GEES total acceleration applied to crewman

GMMV direction of total acceleration with crewman's foot-head axis

GMMB direction of total acceleration projected into the forward/sideways
      plane with respect to crewman's forward direction

ARA1
ARA2 tractor rocket location with respect to the aircraft measured
      in aircraft coordinates
ARA3

Values of Significant Parameters Used in the Simulation Study

Towline

Length	10 feet
Diameter	2 strands 0.42 inch
Elasticity	2800 pounds force/foot (total stretch, 2 strands)
Damping	45 pounds force/foot/sec stretch rate
Payout Resistance	5 pounds force, constant during payout
Rope Drag Coefficient	1.2

Rocket

Length	2.36 feet
Towline Attach	1.2 feet aft of center of gravity
Weight	21 pounds
Burning Rate	15.5 pounds/sec
Lateral Drag Area	0.6 ft^2
End on Drag Area	0.086 ft^2
Axial Moment of Inertia	0.007 slug ft^2
Central Moment of Inertia	0.06 slug ft^2
Burning Time	0.5 second
Rocket Ignition	at towline deployment
Rocket Thrust Build-up Time	0.03 second
Rocket Maximum Thrust	2000 pounds

Crewman

Height	6 feet
Distance Head/CG	2.5 feet

Weight (including equip.)	200 pounds
Distribution - Center of Mass/ Center of Aero Press.	0.5 foot
Axial Moment of Inertia	1.5 slug ft^2
Perpendicular Moment of Inertia	8 slug ft^2
Frontal Drag Area	10 ft^2
Lateral Drag Area	7 ft^2
Head-on Drag Area	1.2 ft^2

Escape System

Seat Back Angle	7° aft of vertical
Rocket Catapult angle	13° ahead of vertical
Rocket Catapult Velocity	115 ft/sec
Rocket Location	1.7 feet aft of crewman; 2.6 feet above crewman
Seat Back Friction Coefficient	0.1
Rocket Spin Rate	0.0

Aircraft Parameters

Fuselage Structure above Crewman's CG in Seat Aircraft Position	⌐.5 feet

Velocity and maneuver data otherwise read in as selected from NATC test data.

In the event the value of any input parameter for a simulated ejection was changed, the changed value for that run will be given in the top-right hand corner of the appropriate figure. (In the case of Figs. 33 through 40 the rocket catapult angle was increased to 27° ahead of vertical.)

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VI. DISCUSSION OF RESULTS

Figures 2 through 9 include a condensed representation of the A1H/J aircraft flight motions as extracted from the NATC report. The aircraft flight conditions are labeled with numbers 1 through 23, and correspond to those data samples specified by the Naval Air Systems Command for input into the ejection system simulation. Figures 10 through 32 should be referenced by their condition number, which correspond to the aircraft maneuvers as appear in Figs. 2 through 9. Figures 33 through 40, duplicating conditions 1 through 5 and 8 through 10 in the manner already described, attach the letter "b" to their condition number (i. e., 1b through 5b and 8b through 10b). These then represent the data requested by the Naval Air Systems Command. The success/failure of ejection in these runs needs to be considered on three major factors in order of decreasing significance.

1. Did the ejection system succeed in removing the crewman from the cockpit at all.

2. If ejected, did the crewman's trajectory have a suitable shape to carry him clear of the aircraft envelope.

3. Were the forces imposed upon the crewman within levels not causing severe injury.

Based upon criteria (1) and (2), all ejection simulated with the tractor rocket launched 13° ahead of the aircraft vertical were successful except for conditions 8 and 9. When the rocket was launched at 27° instead of 13° forward of vertical, a successful ejection was simulated for

condition 9 but escape failure resulted for condition 5 as well as condition 8.

Any decision as to the degree of injury the crewman would experience must be left to the judgement of specialists trained in aviation medicine and physiology. Such an evaluation might be made from the plots of forces upon the aircrewman included on each figure.

These runs were made with the specific system parameters and crewman weight indicated. In general, changes in these parameters will effect the success of escape. In particular, the following factors are noteworthy qualitative relationships that are relevant. (These are inferred from basic physical laws and not from these simulation studies.)

1. Decrease in rocket thrust will increase the time required for the crewman to escape and will, in the presence of aircraft rotation, reduce the crewman's probability of escape. Increase in rocket thrust will decrease time to emergence and hence increase allowable values of aircraft rotational rates for which escape is successful.

2. Increase of crewman's equipped weight affects the crewman's escape velocity inversely for a given rocket thrust level. This increase in crewman's weight will have an analogous effect as decrease in rocket thrust and visaversa.

3. Increase in the forward tilt angle of the rocket catapult provides a compensation for higher forward flight speed, but for rotating aircraft at slow speeds increases the pull angle between the tractor rocket and the crewman's seat track along which he must emerge. This can be seen by

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comparing crewman escape trajectories in Figs. 10 through 15 and 18 through 20 (conditions 1 through 5 and 8 through 10) with figures 33 through 40 (conditions 1b through 5b and 8b through 10b).

Prior to the present simulation project, the effects of aircraft flight speed had been studied at the Applied Physics Laboratory in a two-dimensional, three-degree-of-freedom digital simulation described in Ref. 3, but this simulation was unable to reproduce the effects of aircraft out-of-control motions. On this account the Naval Air Systems Command requested that the Applied Physics Laboratory produce a six-degree-of-freedom tractor rocket ejection escape system simulation to permit simulation of aircrew ejection trajectories from out-of-control aircraft possessing motions such as are described in the Naval Air Test Center, Patuxent, report, Ref. 2. The simulation described in this report was produced to meet this need.

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Fig. 1 Test of Tractor Rocket Escape System
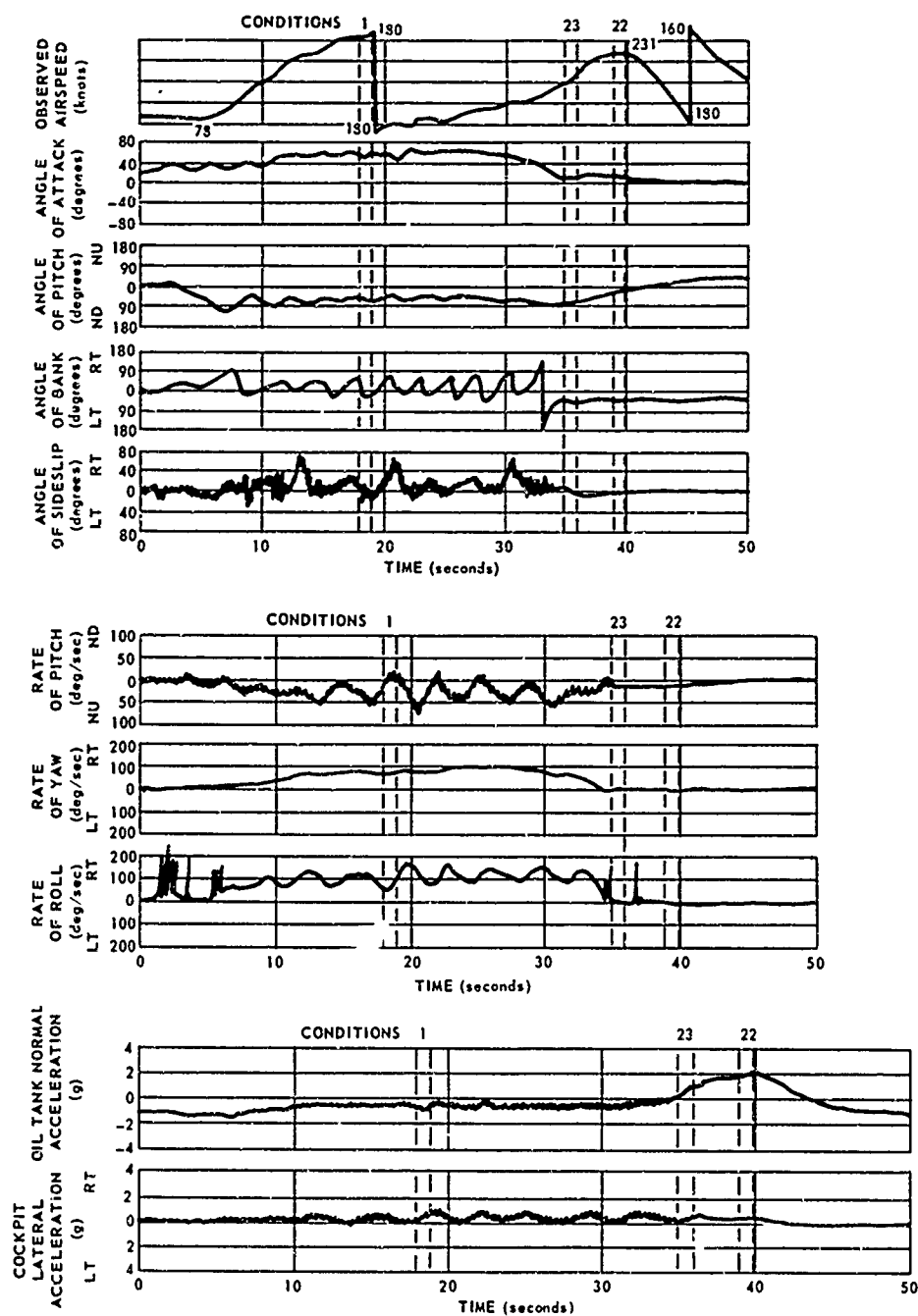
Fig. 2   Aircraft Flight Simulation Conditions Nos. 1, 22, and 23
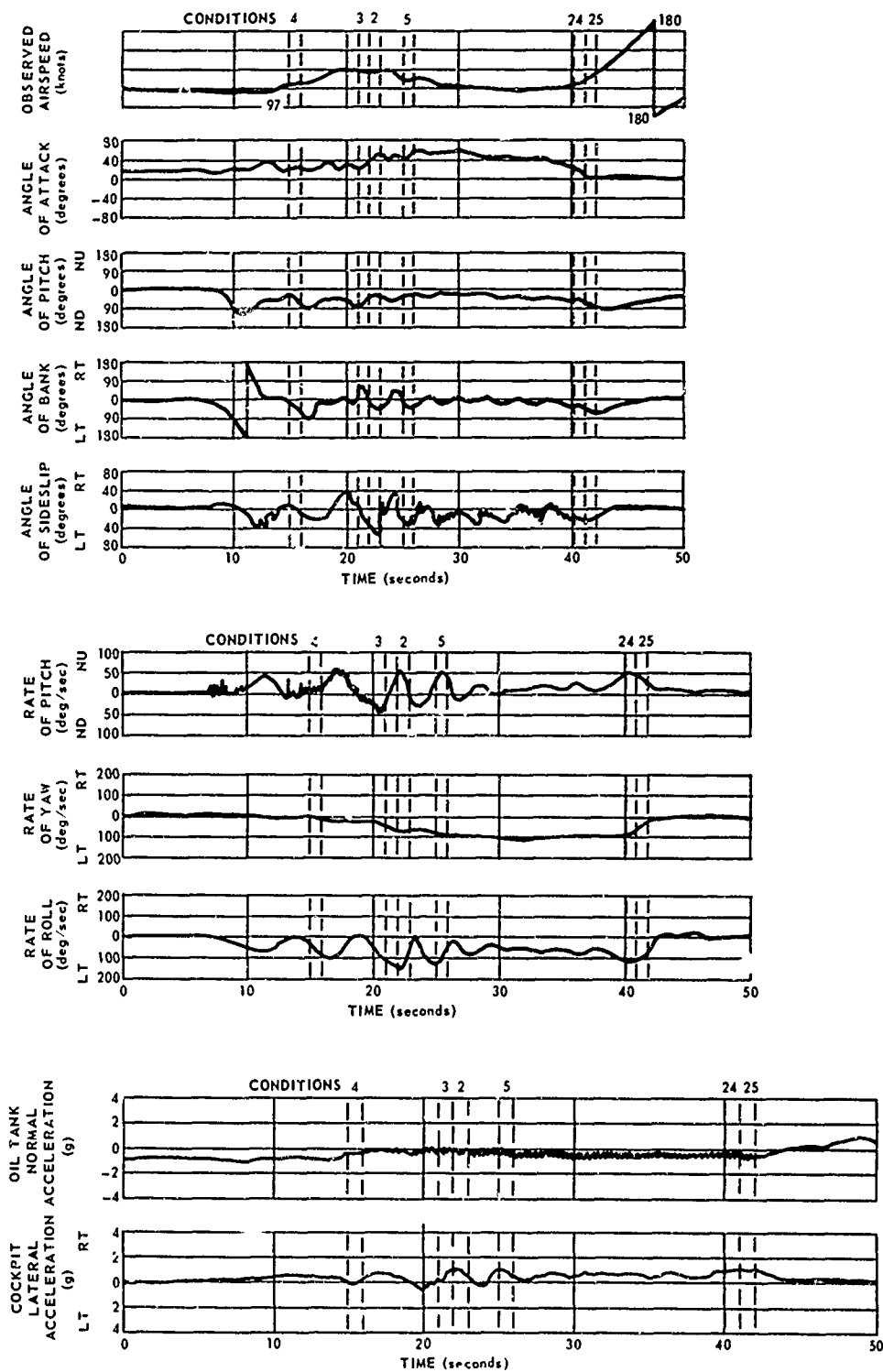
Fig. 3   Aircraft Flight Simulation Conditions Nos. 2 through 5
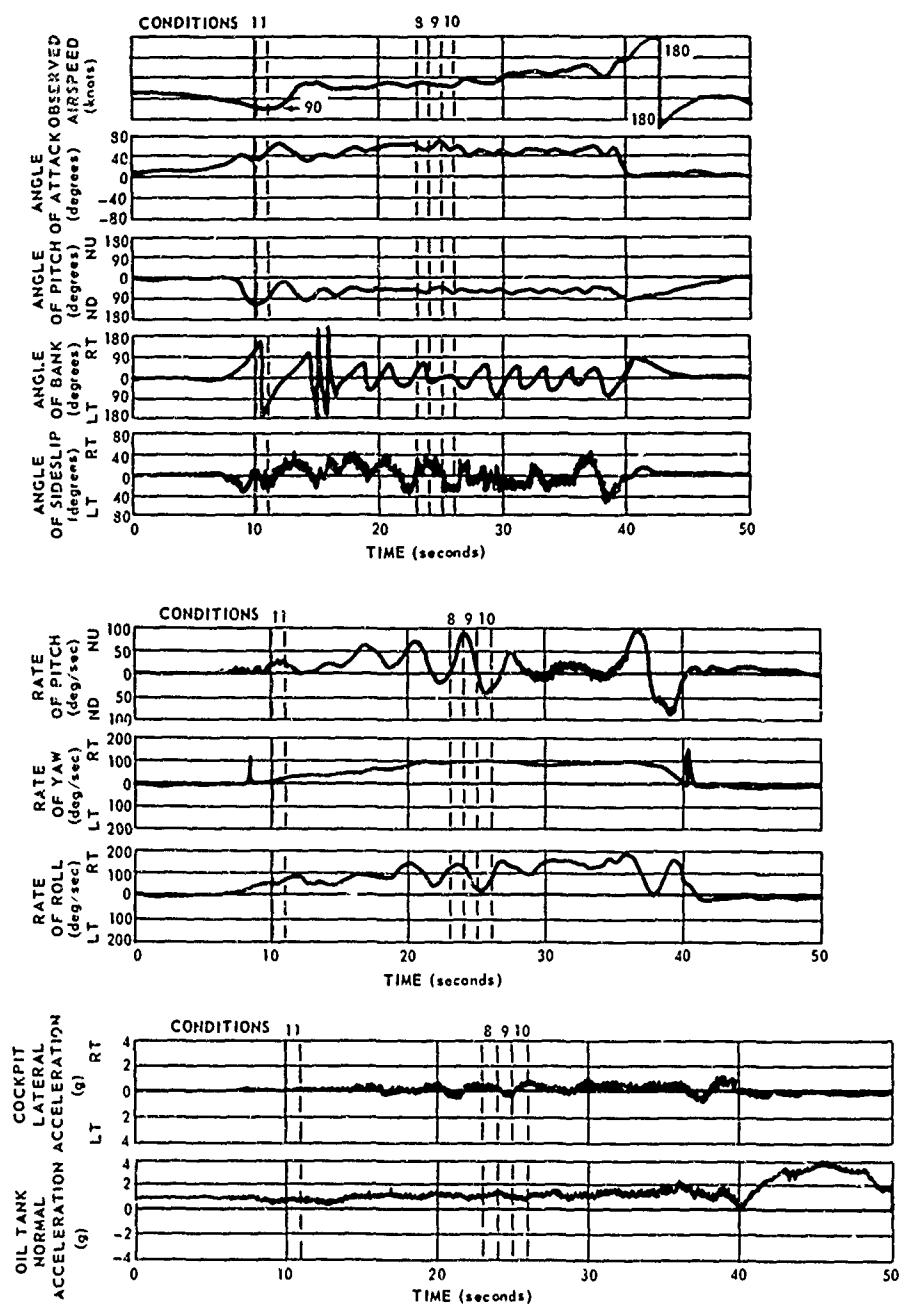
Fig. 4   Aircraft Flight Simulation Conditions Nos. 8 through 11
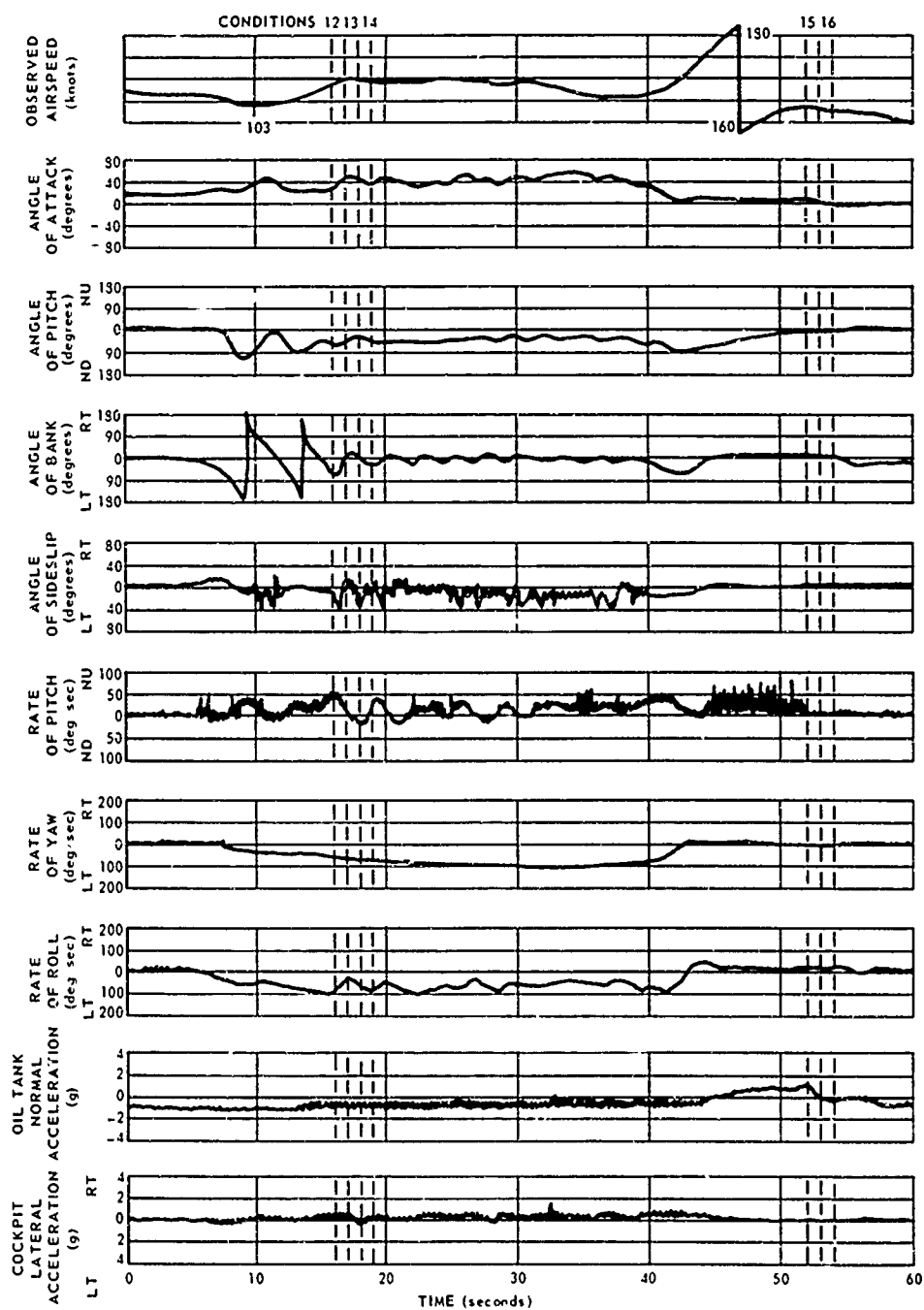
Fig. 5   Aircraft Flight Simulation Conditions Nos. 12 through 16
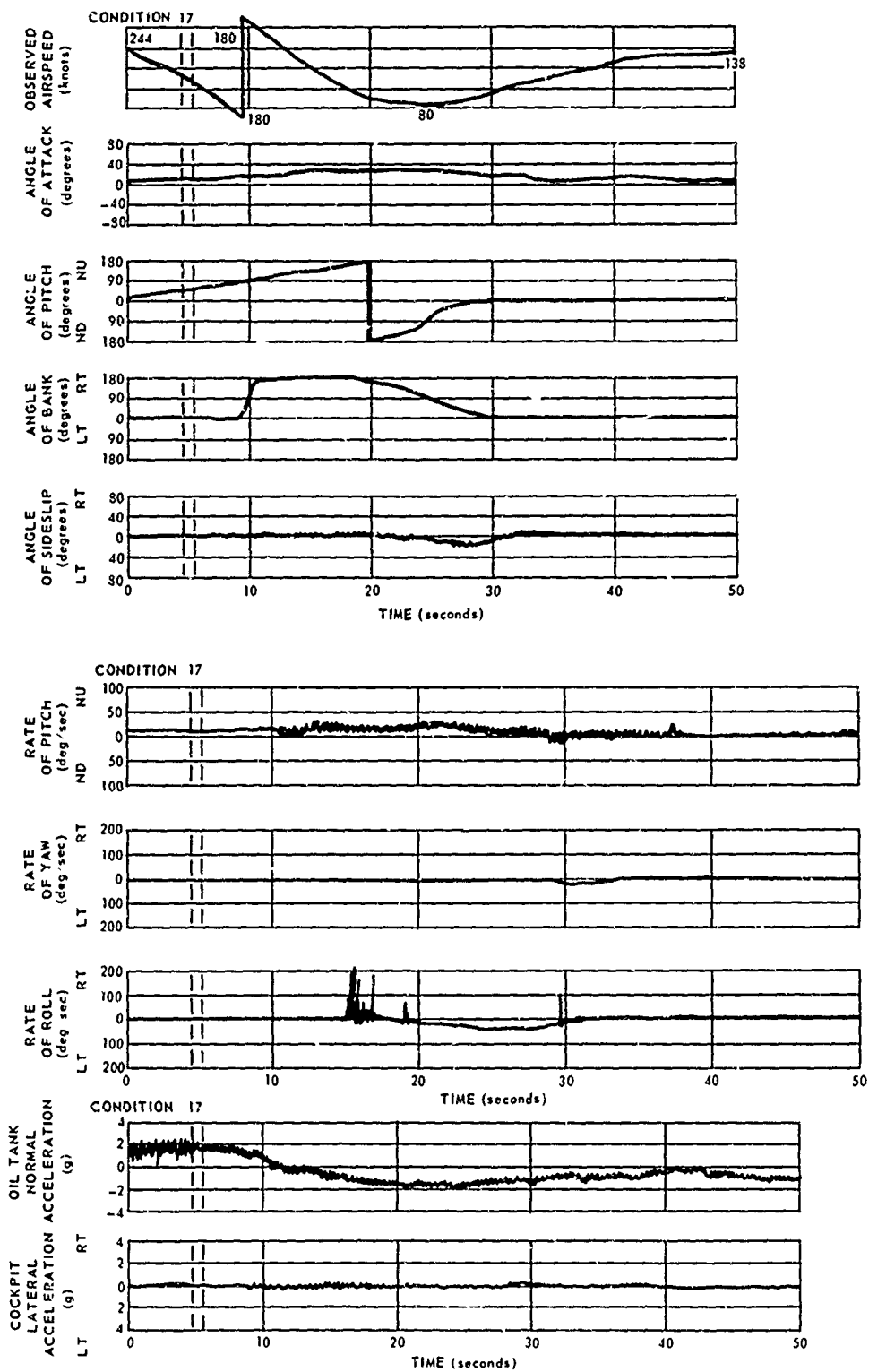
Fig. 6   Aircraft Flight Simulation Condition No. 17
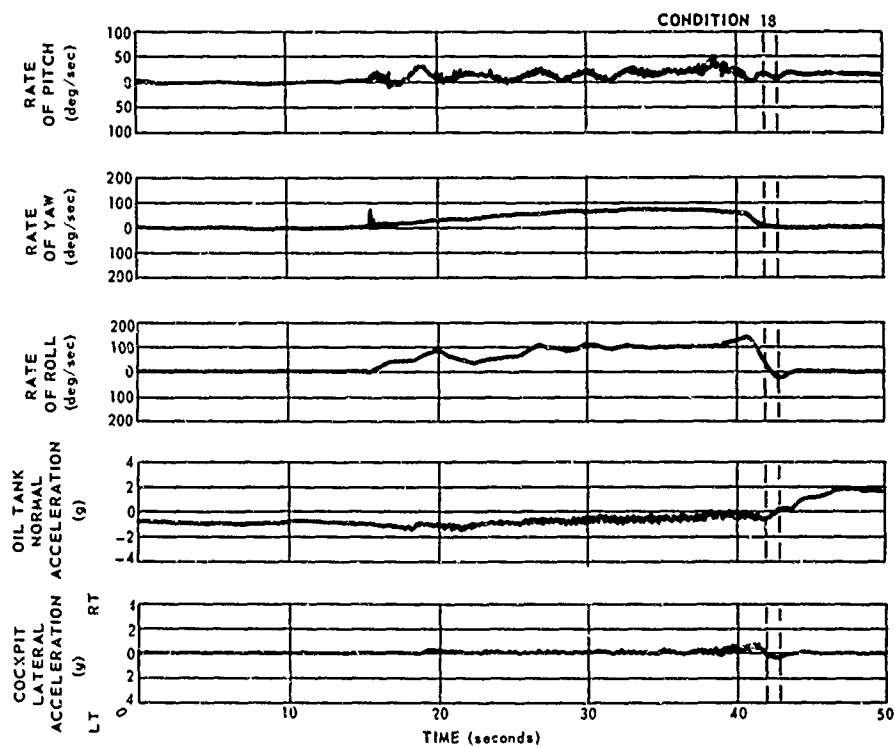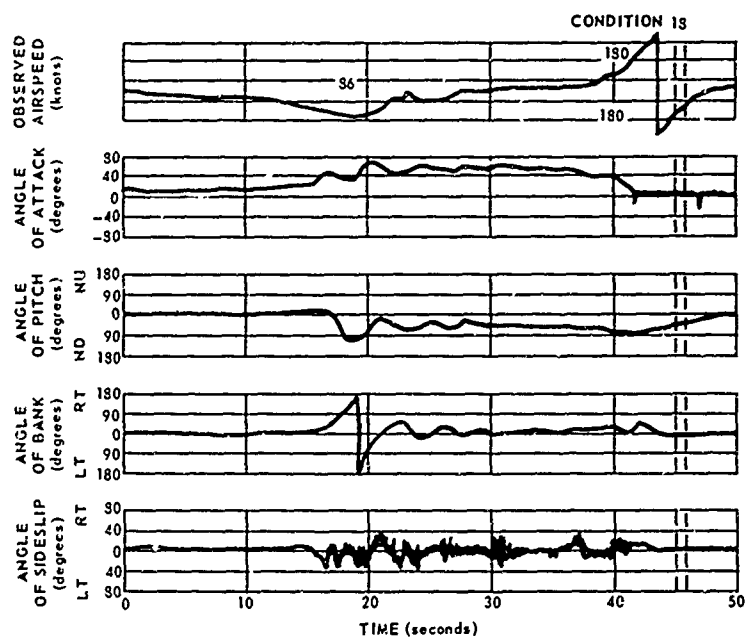
Fig. 7   Aircraft Flight Simulation Condition No. 18
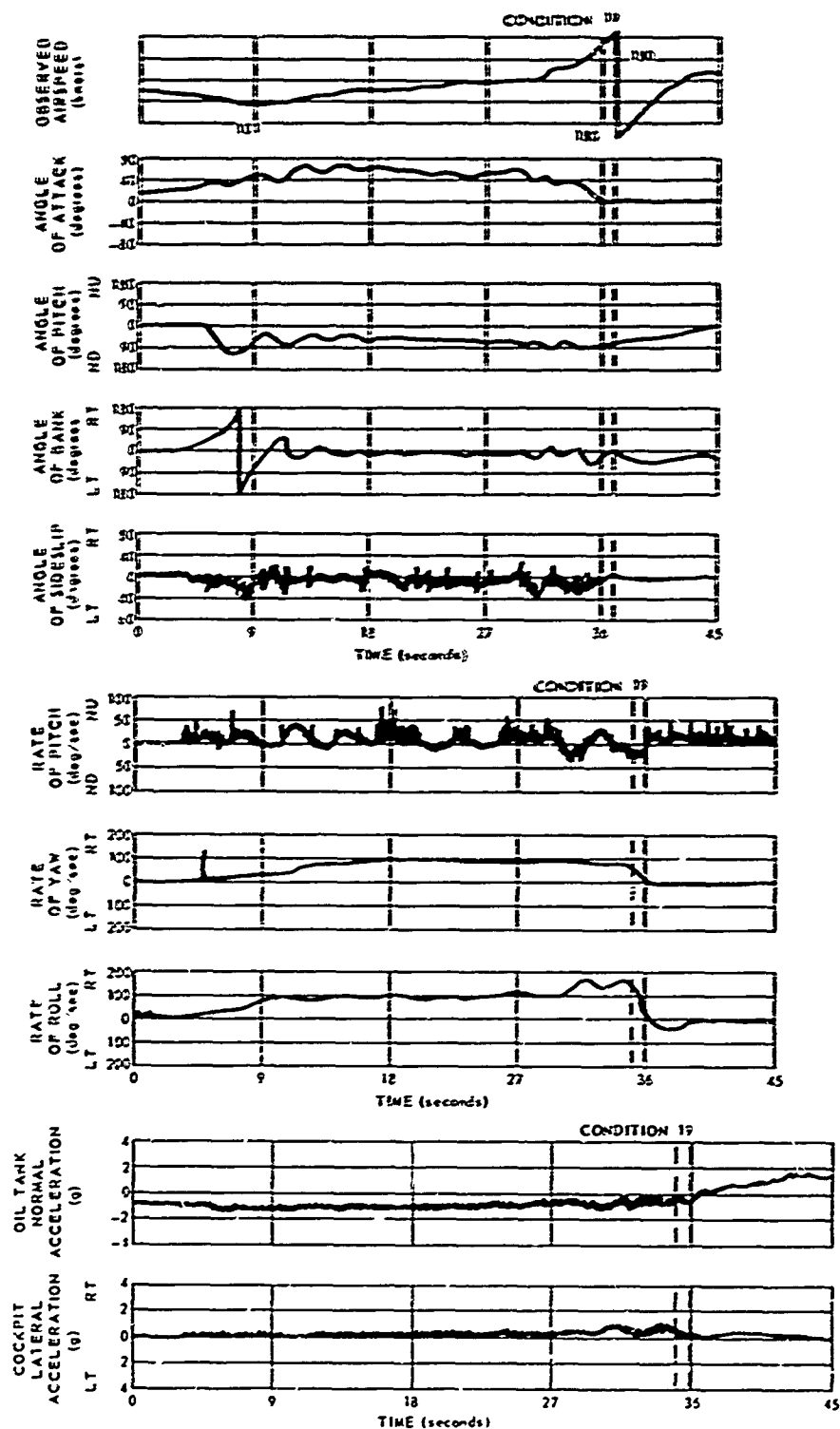
Fig. 8   Aircraft Flight Simulation Condition No. 19
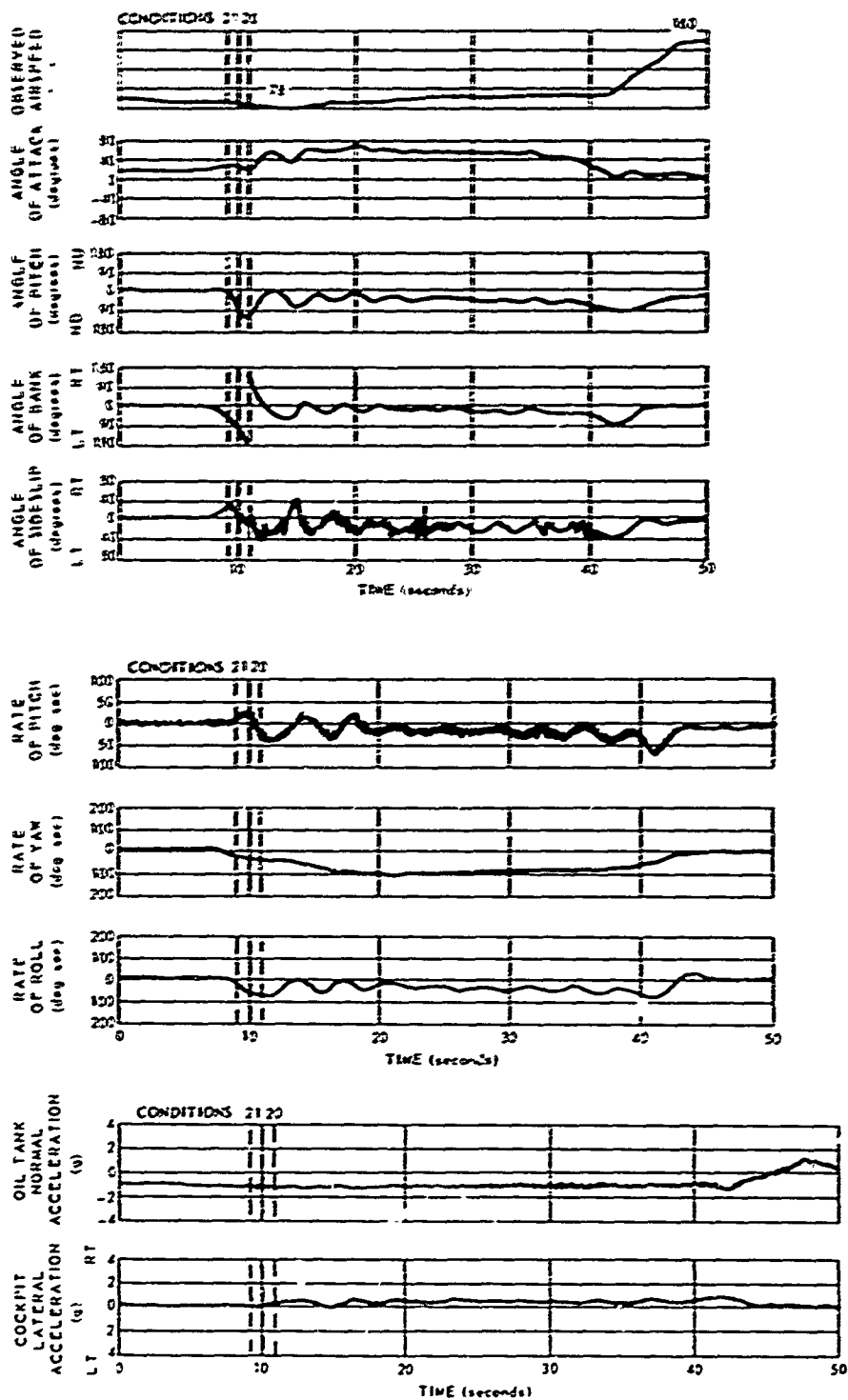
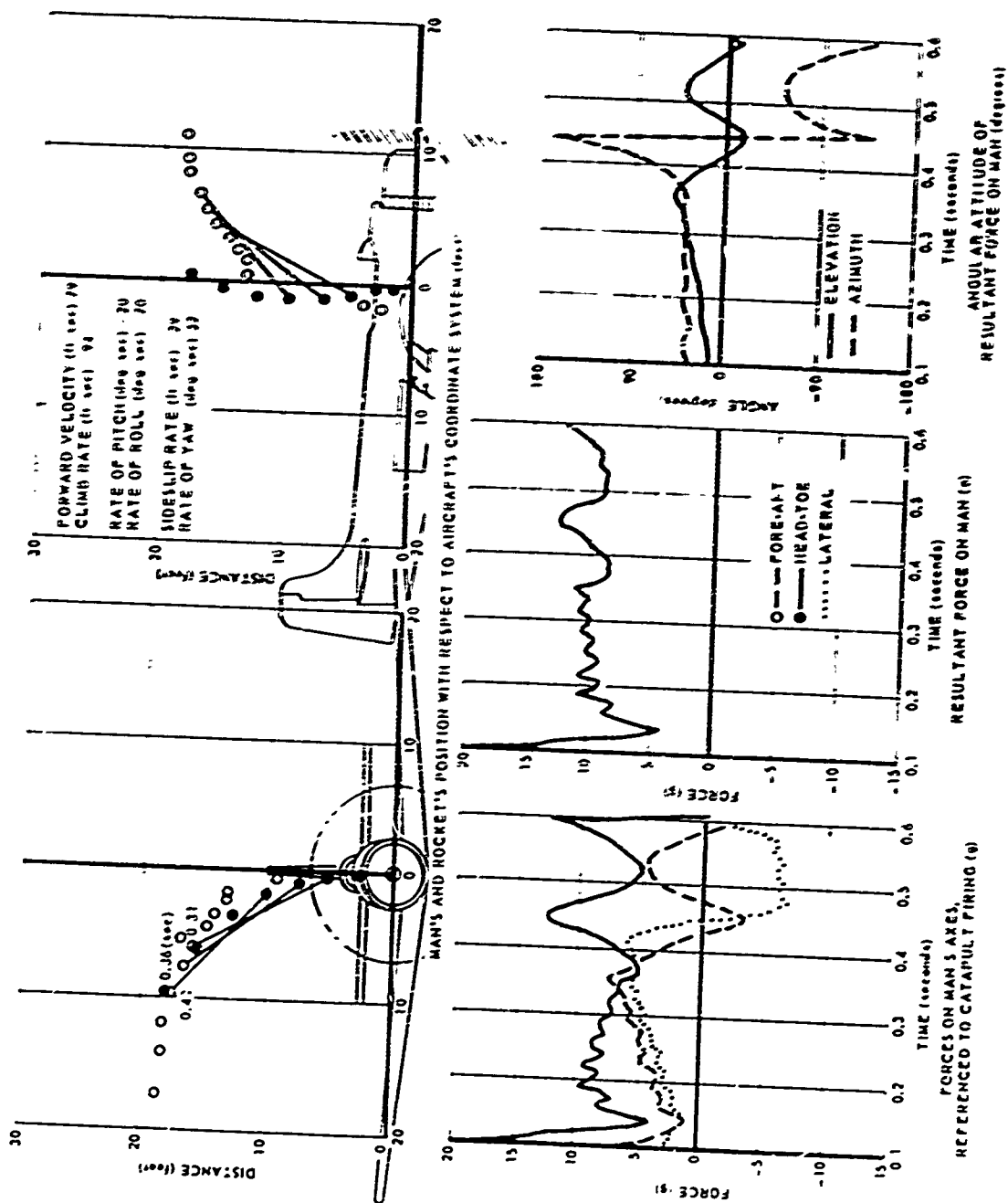Fig. 9   Aircraft Flight Simulation Conditions Nos. 20 and 21
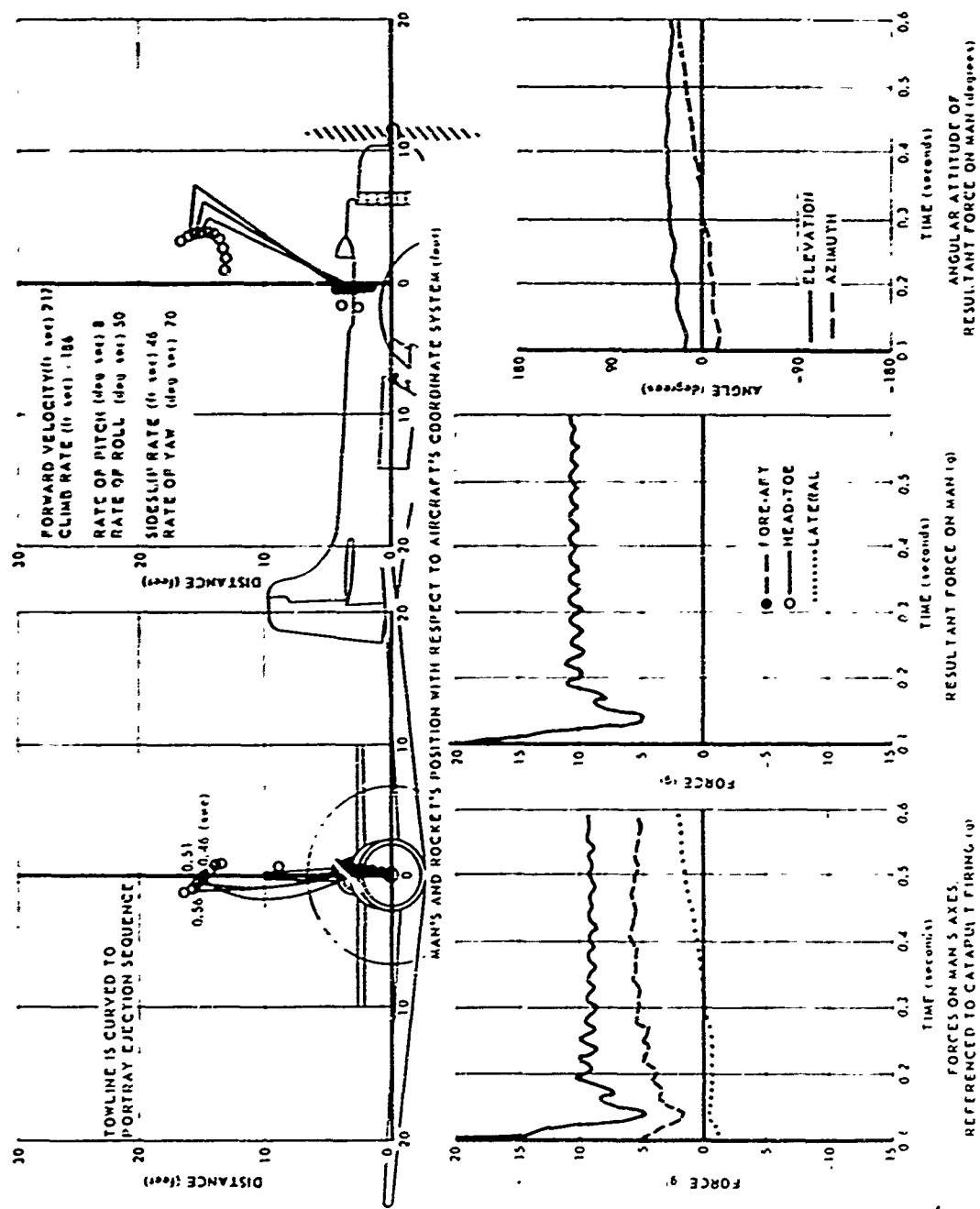
Fig. 10 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 1
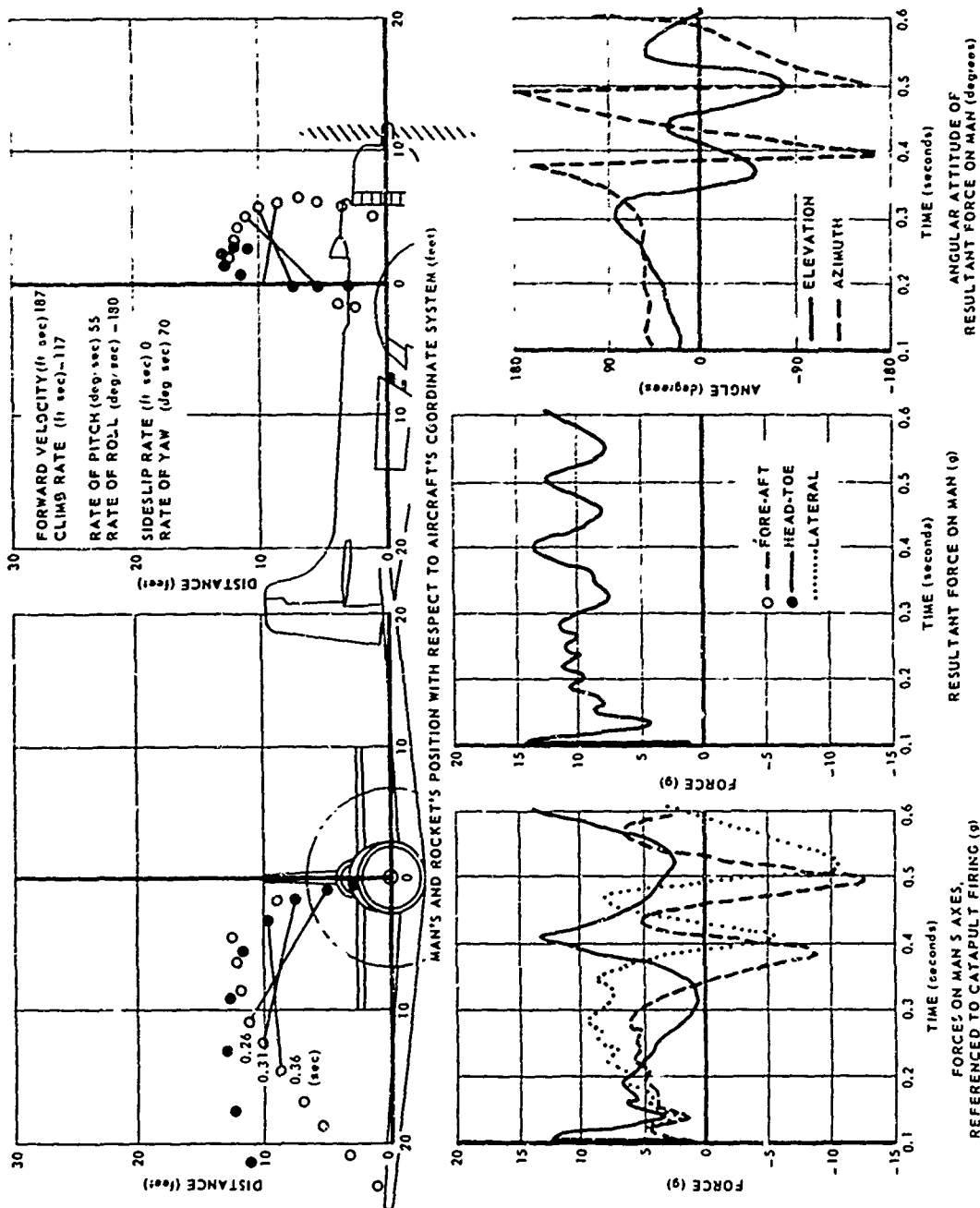
Fig. 11 Simulation Results, Three-Dimensional Tractor Rocket
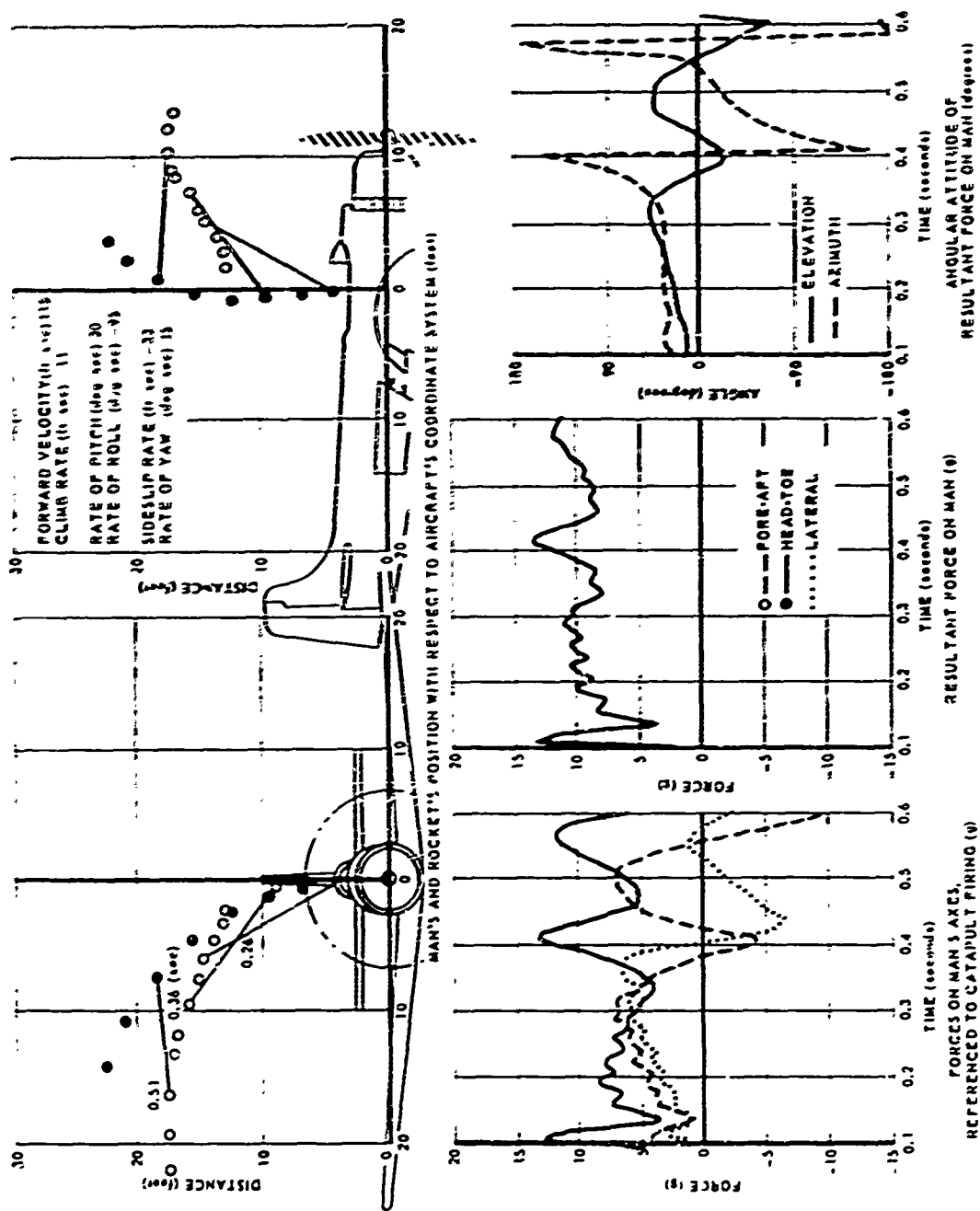Ejection Studies, Condition 2
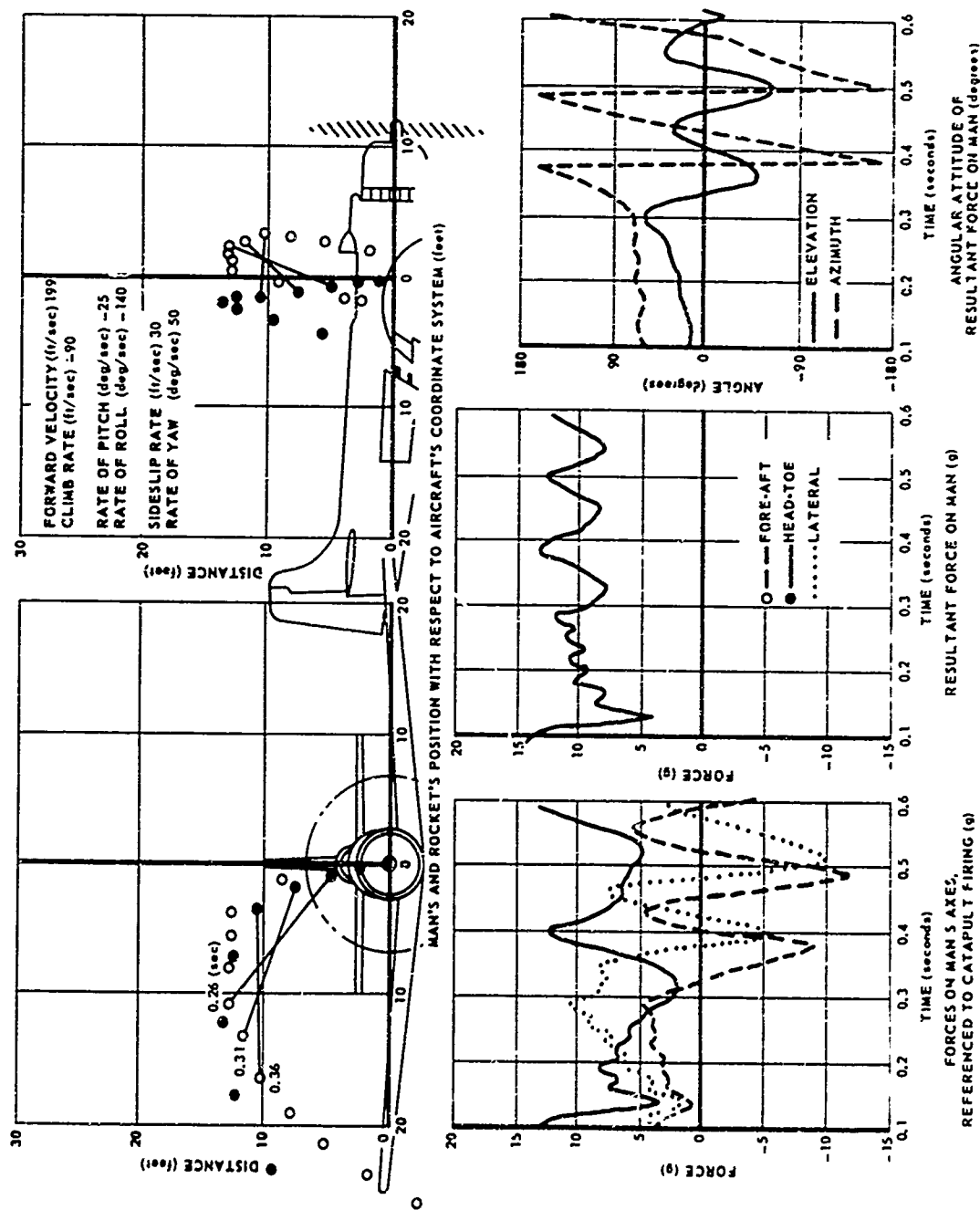
Fig. 12   Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 3
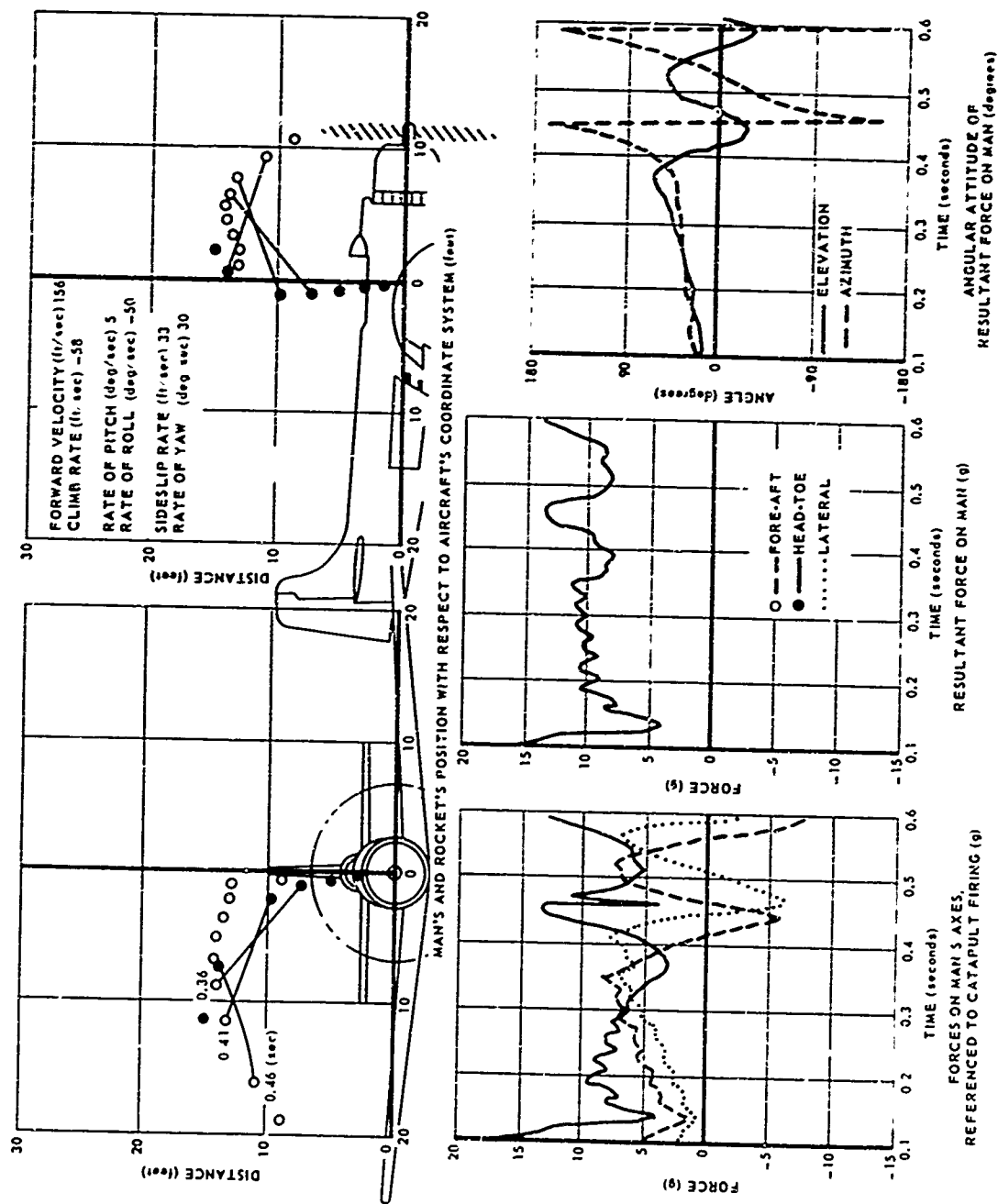
Fig. 13 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 4
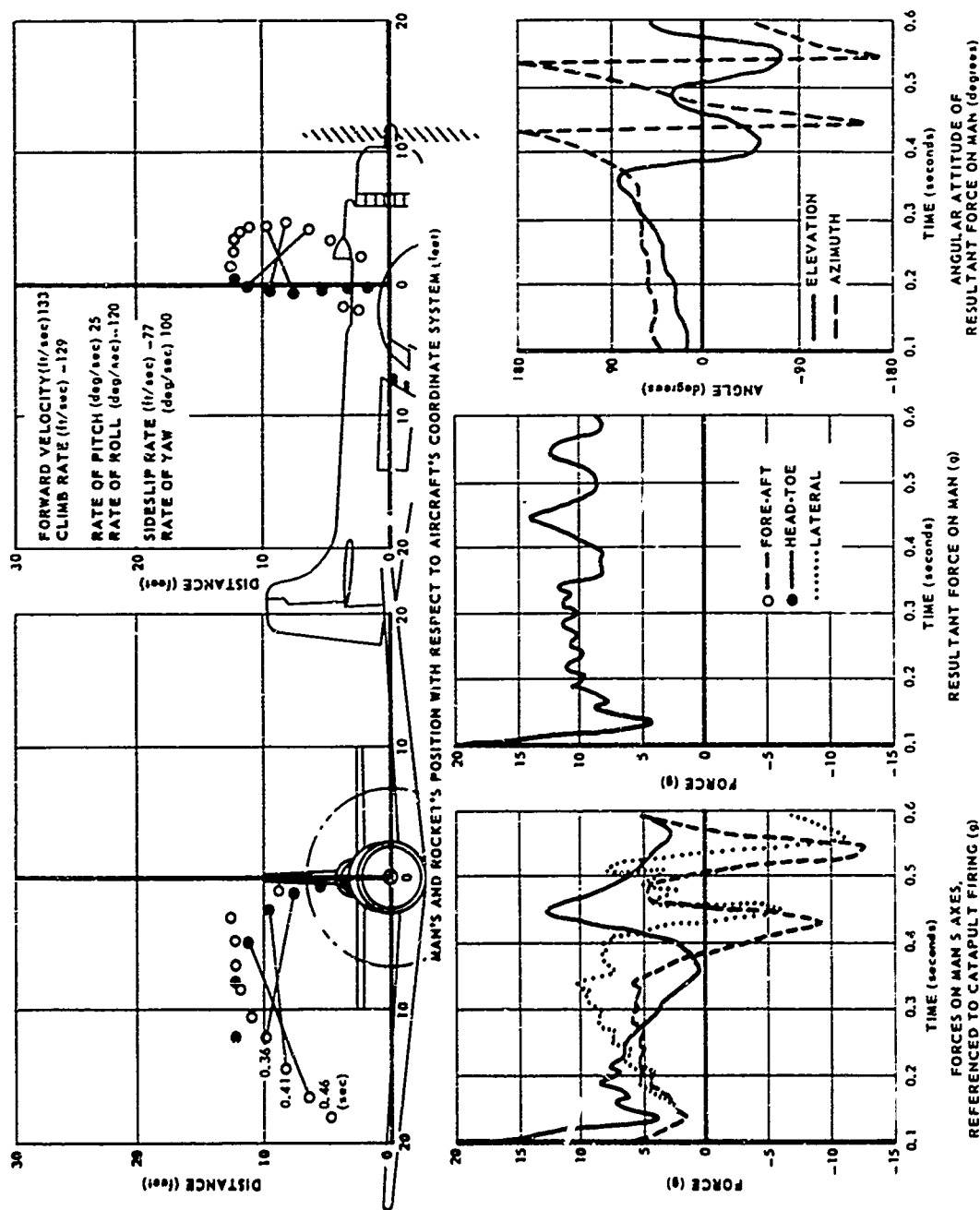
Fig. 14 Simulation Results, Three-Dimensional Tractor Rocket
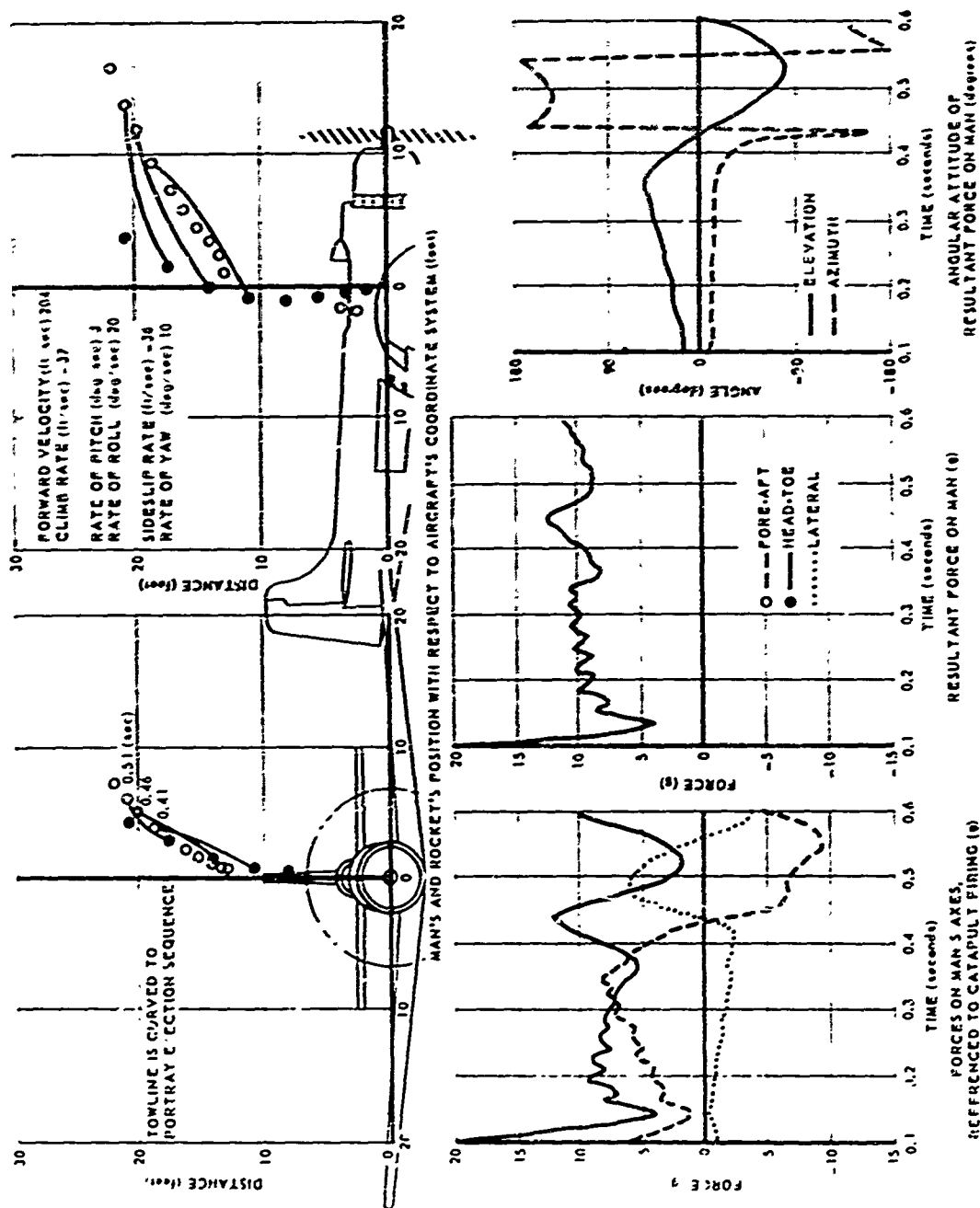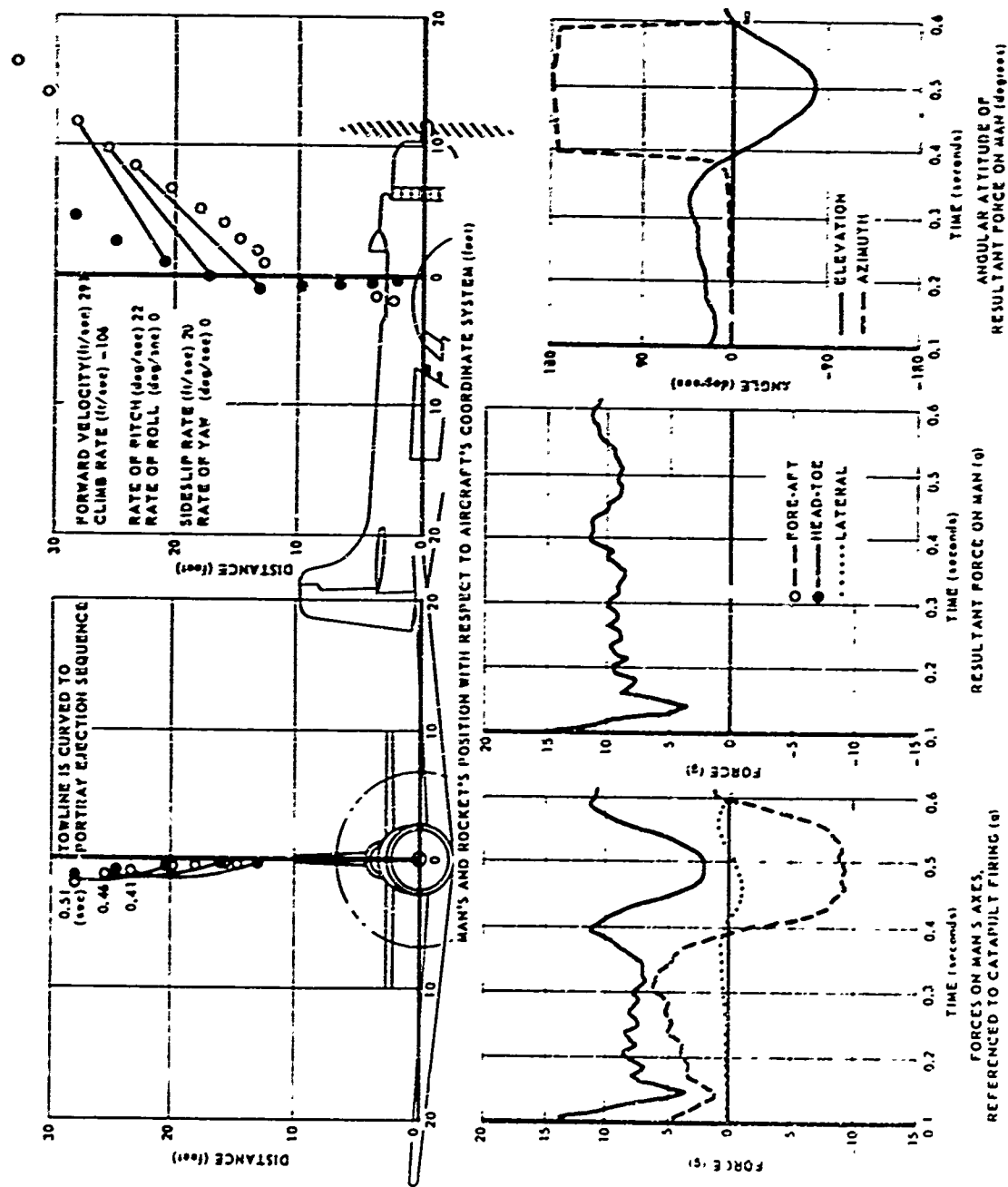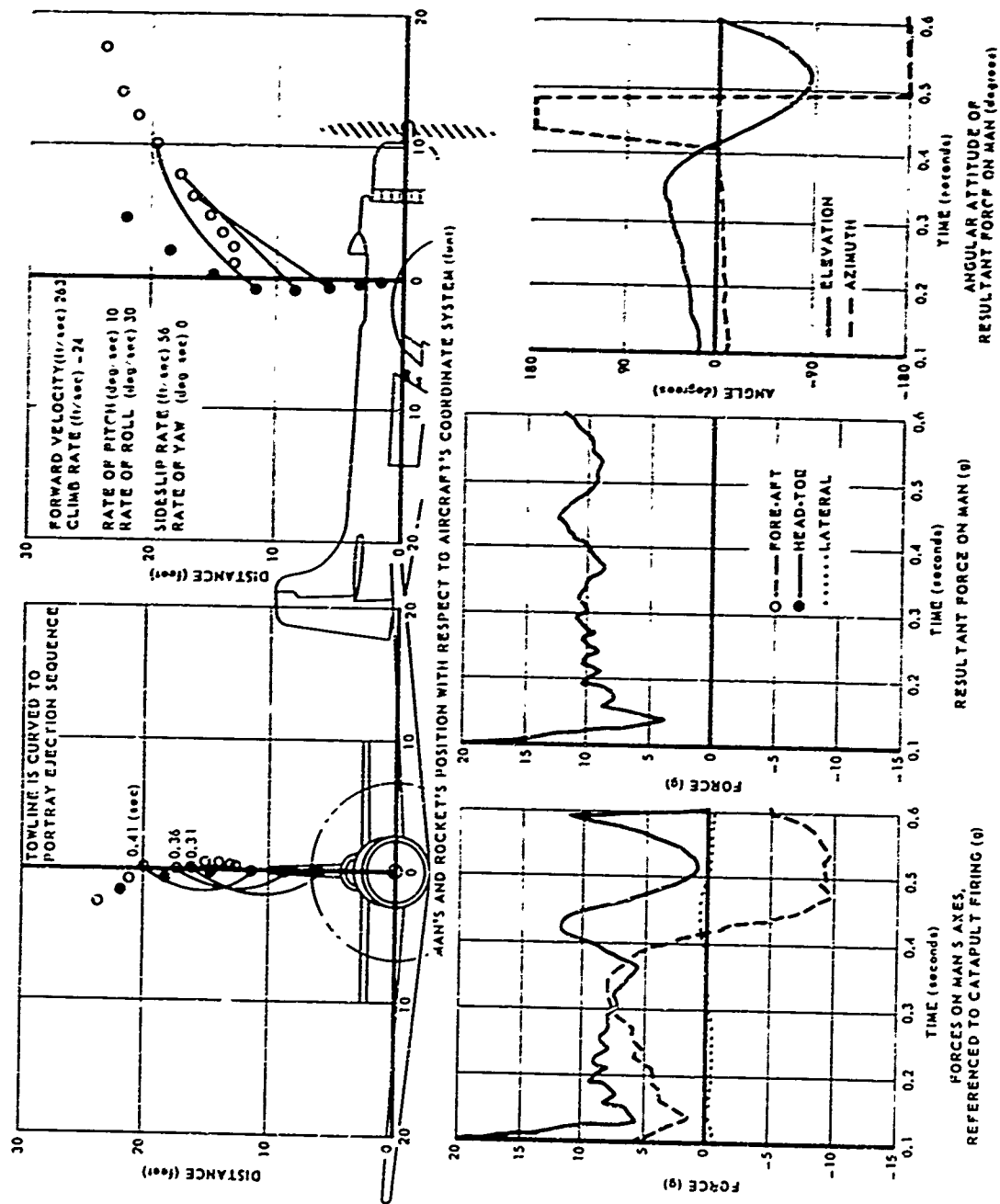Ejection Studies, Condition 5
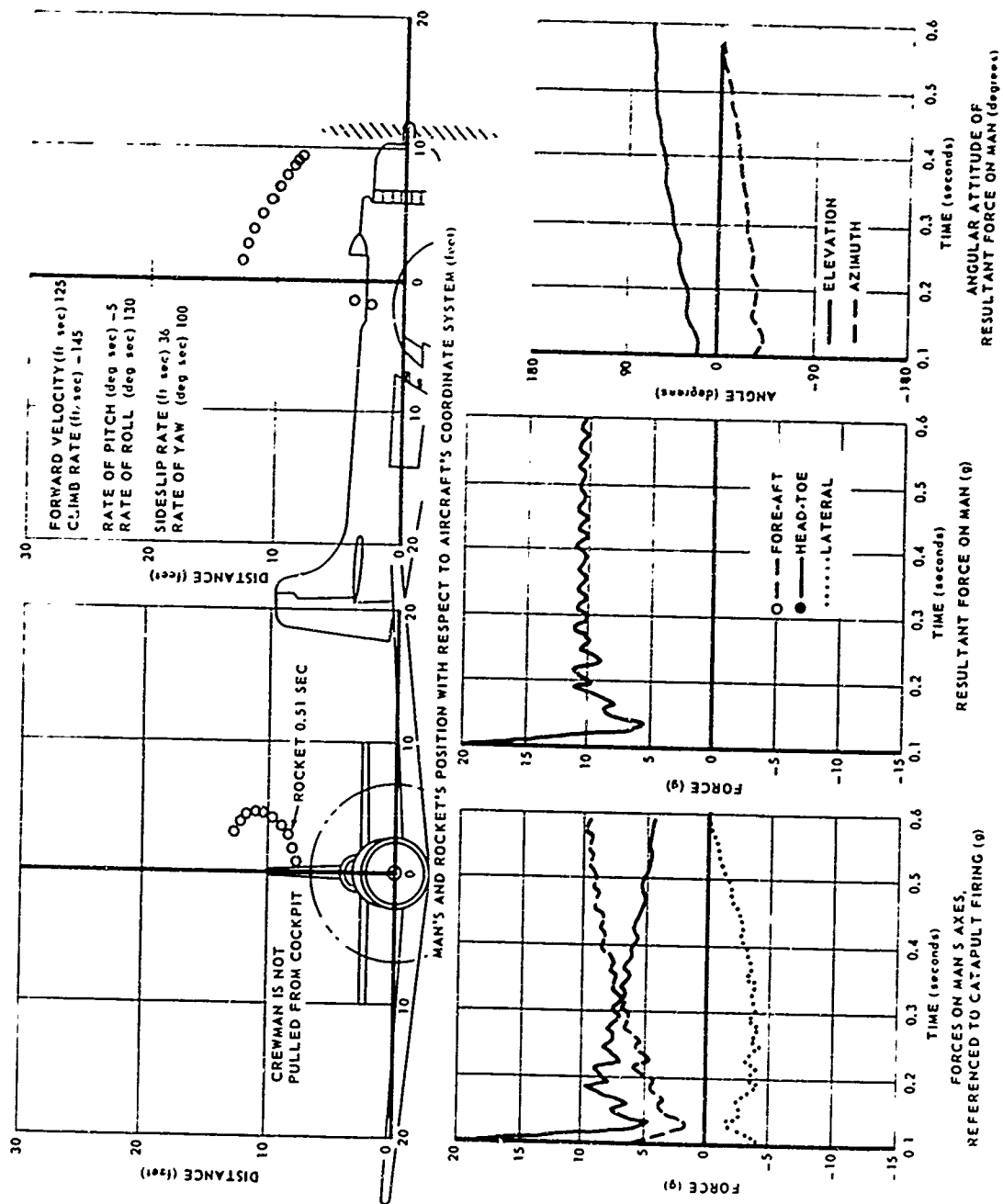
Fig. 15   Simulation Results, Three-Dimensional Tractor Rocket
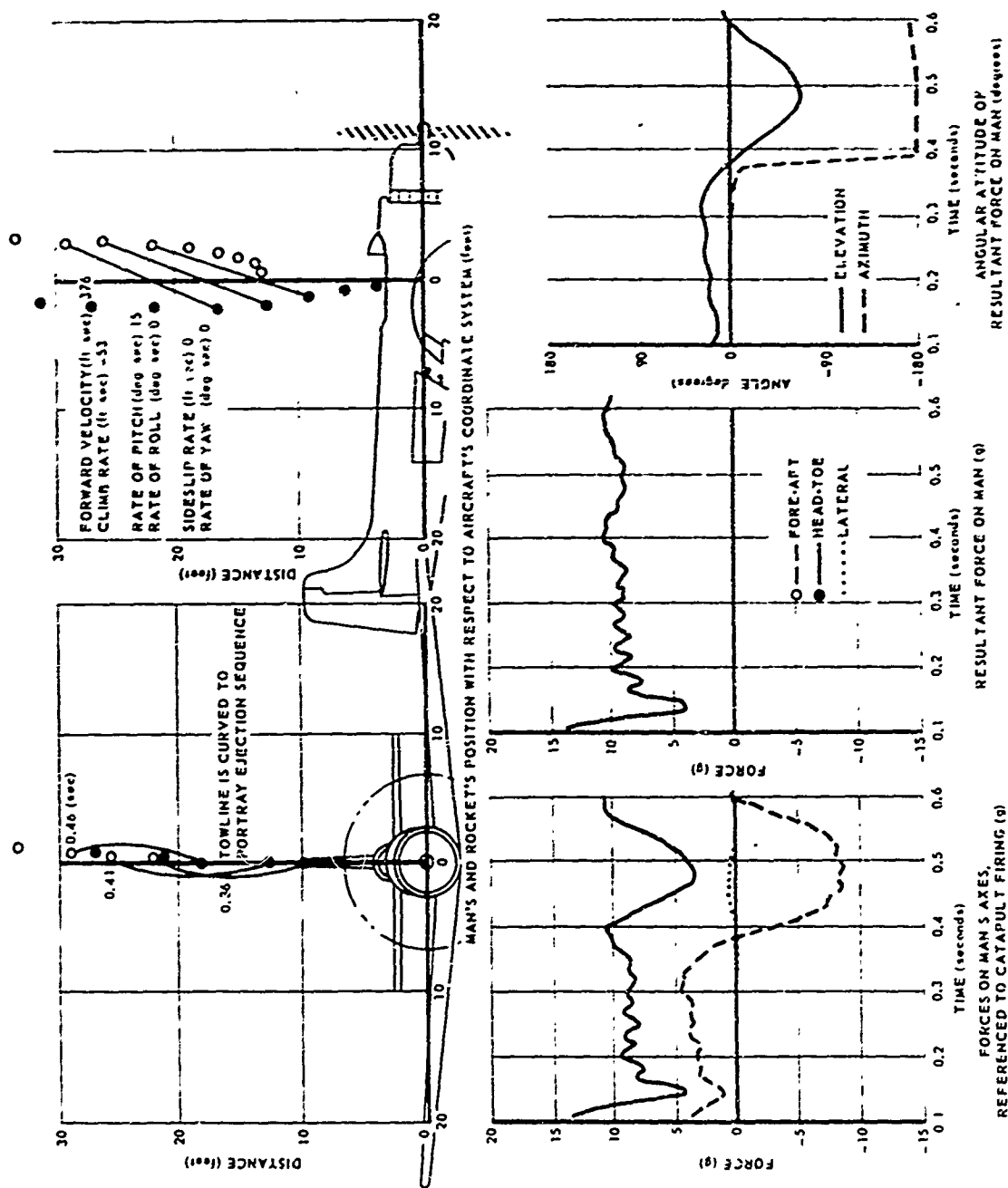Ejection Studies, Condition 8
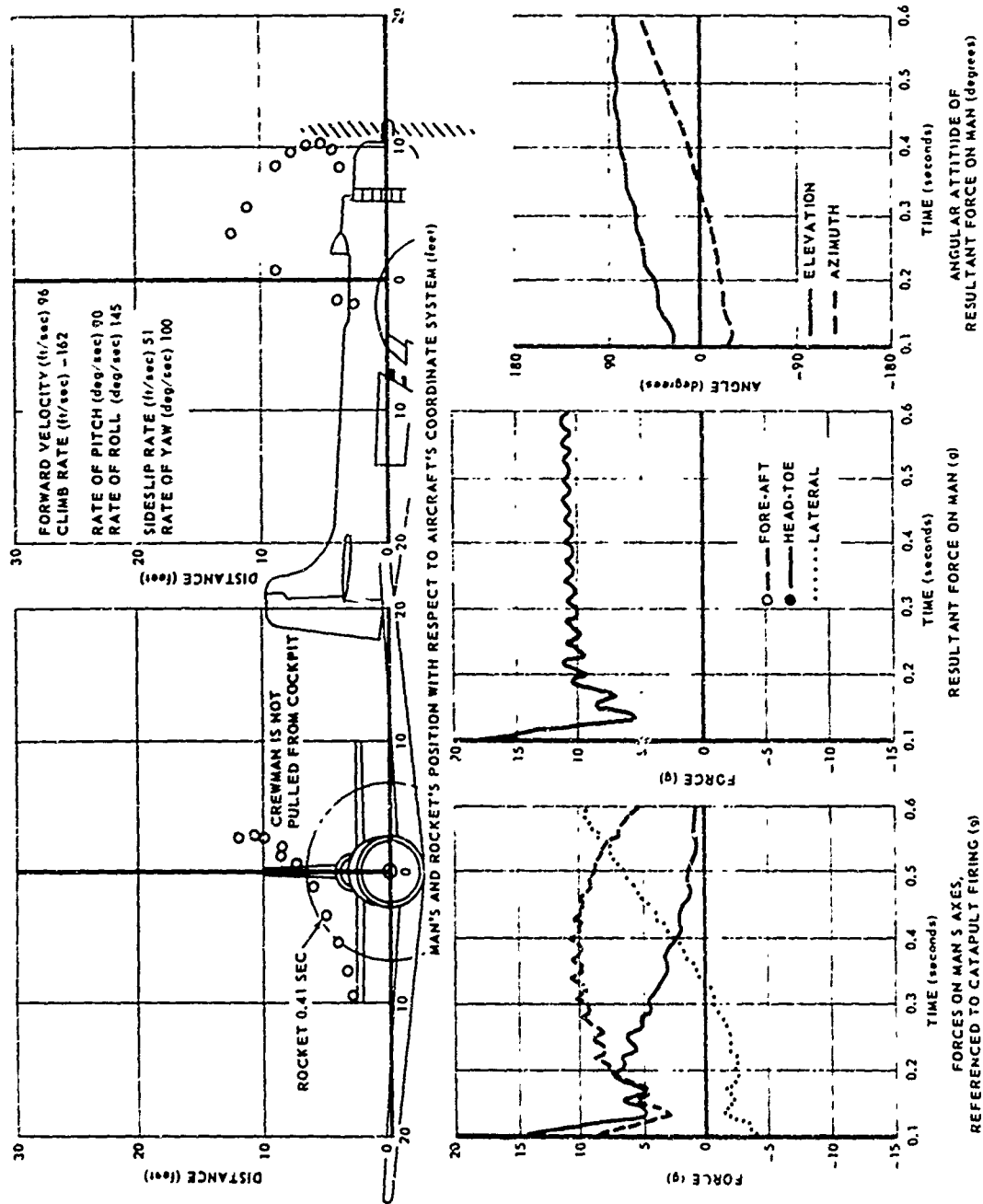
Fig. 16 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 9
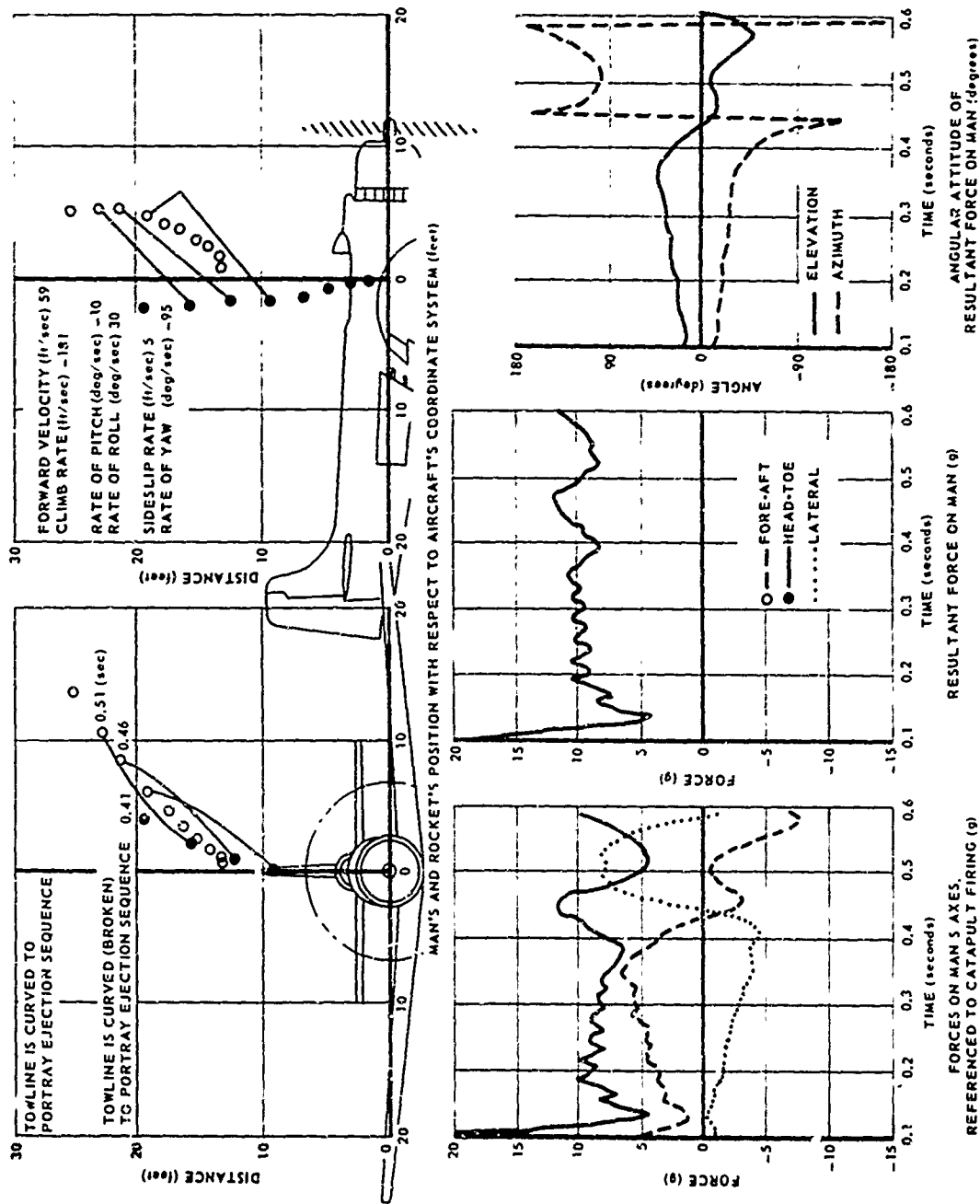
Fig. 17 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 10
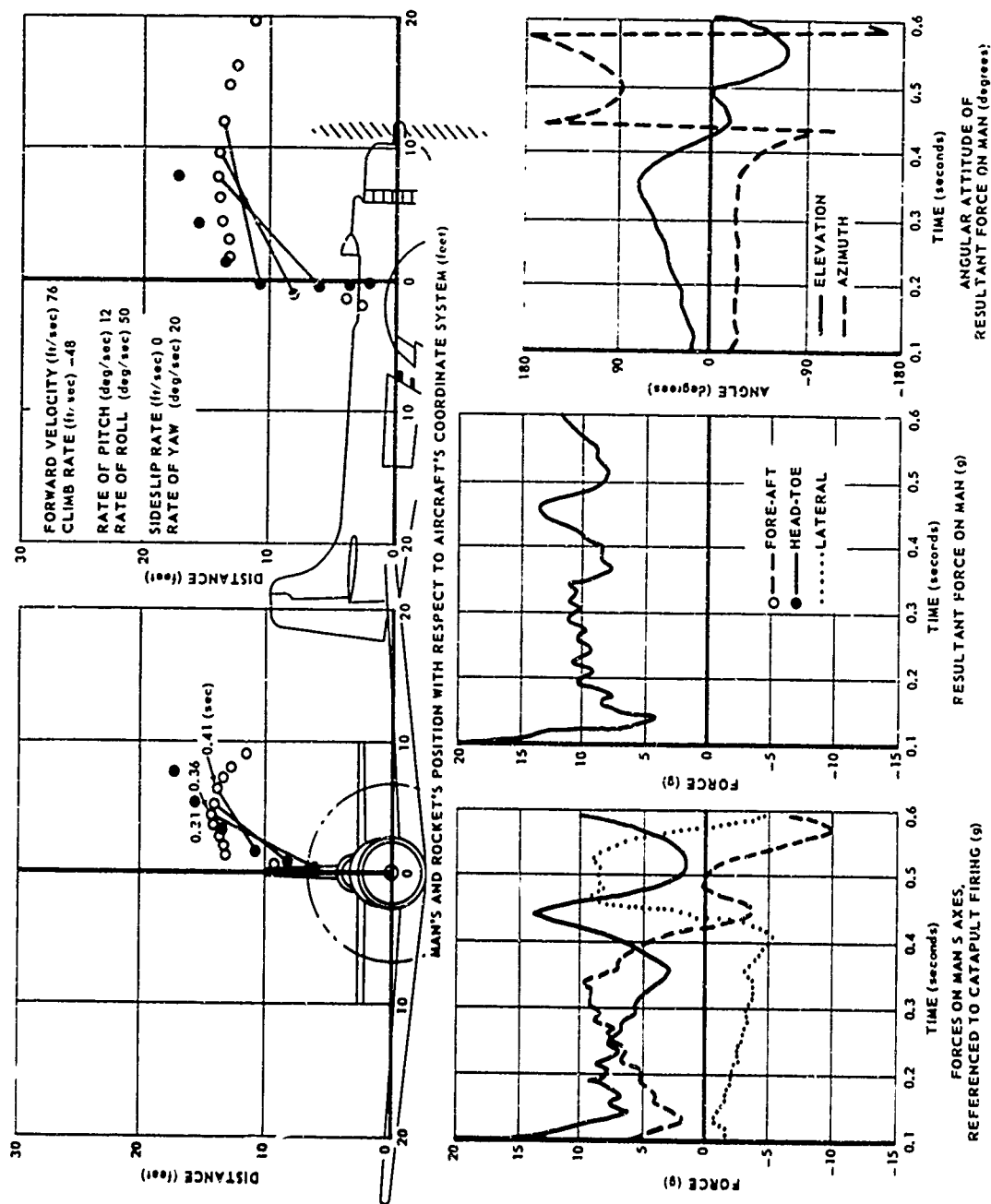
Fig. 18 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 11
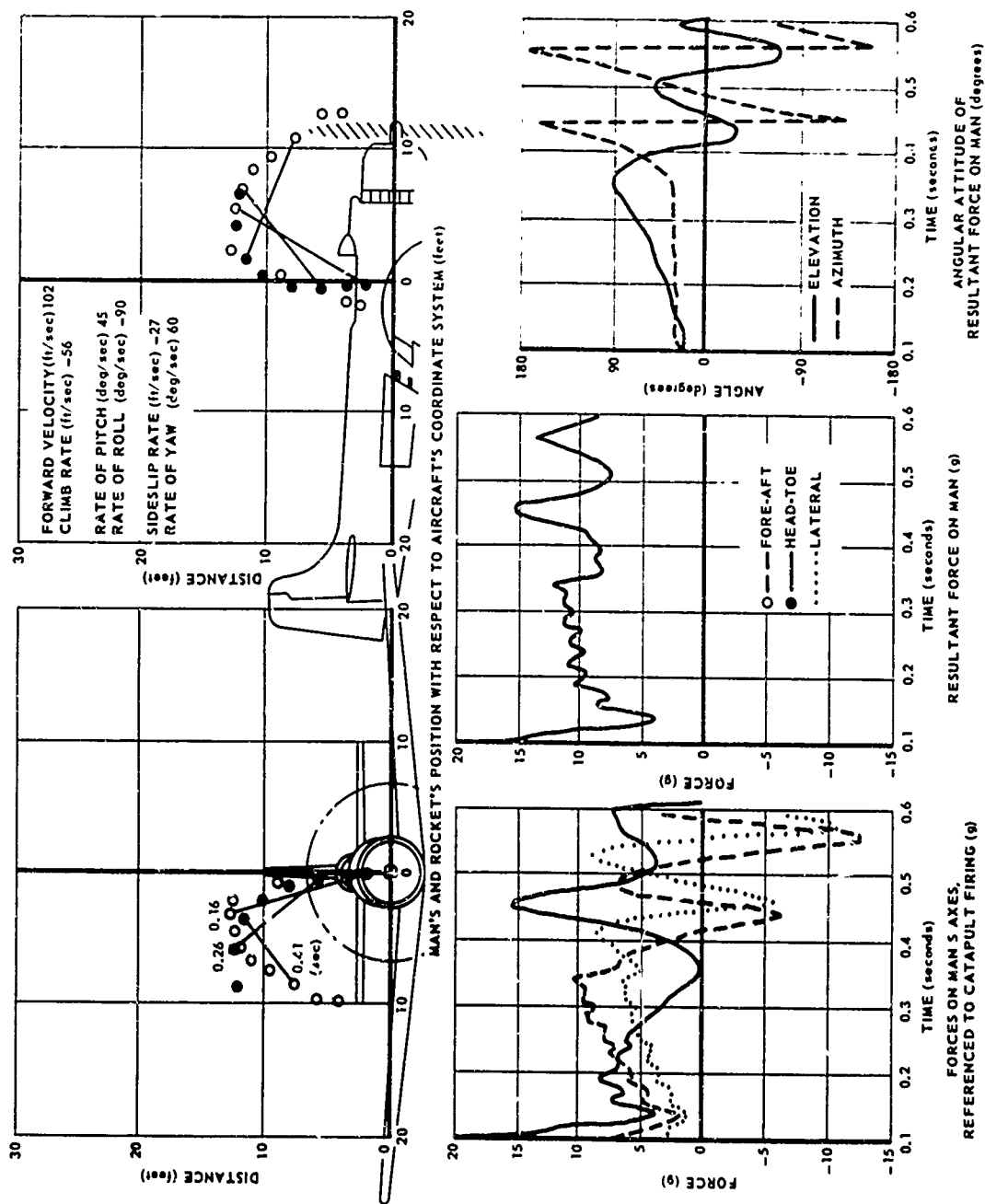
Fig. 19 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 12
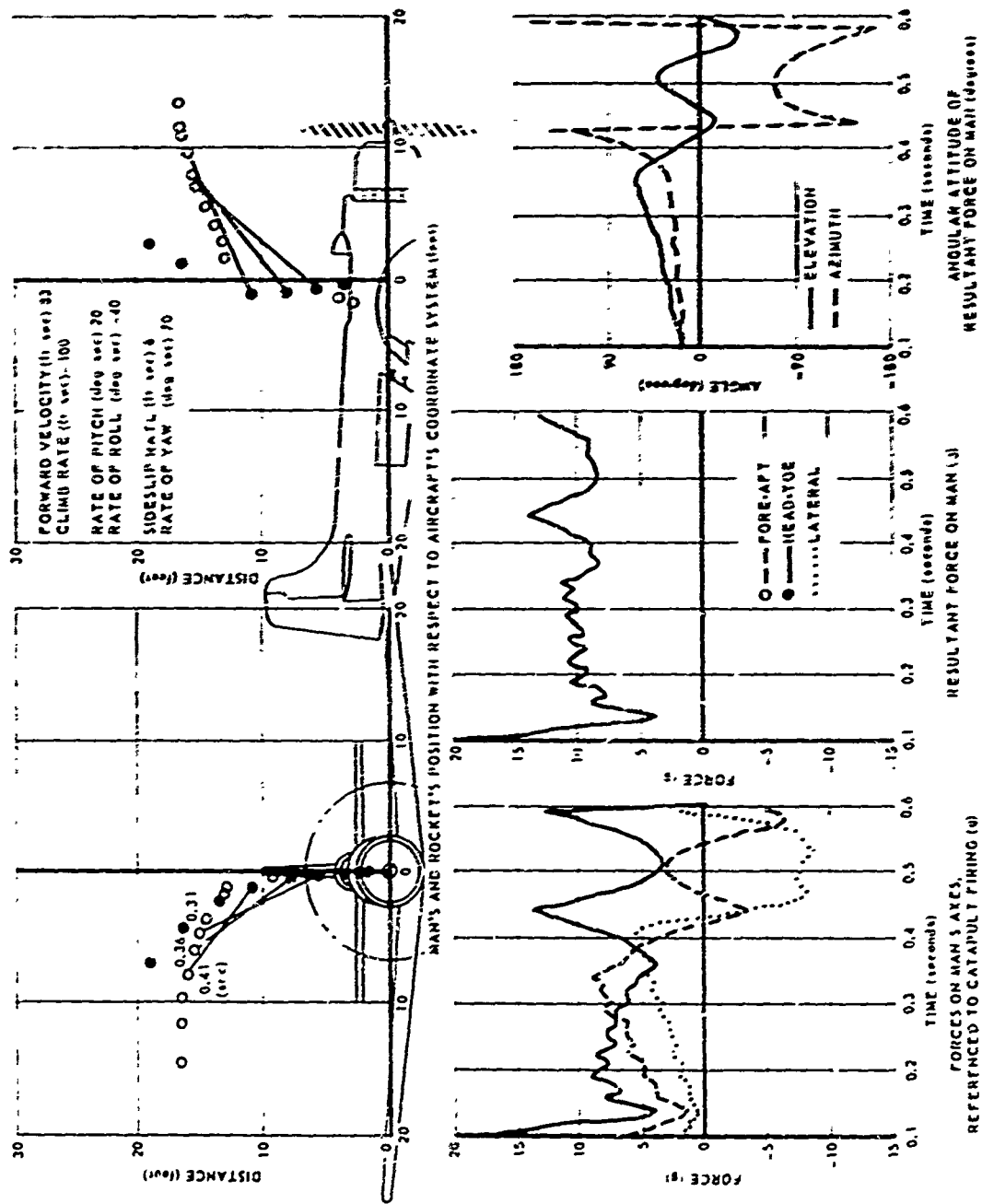
Fig. 20 Simulation Results, Three-Dimensional Tractor Rocket
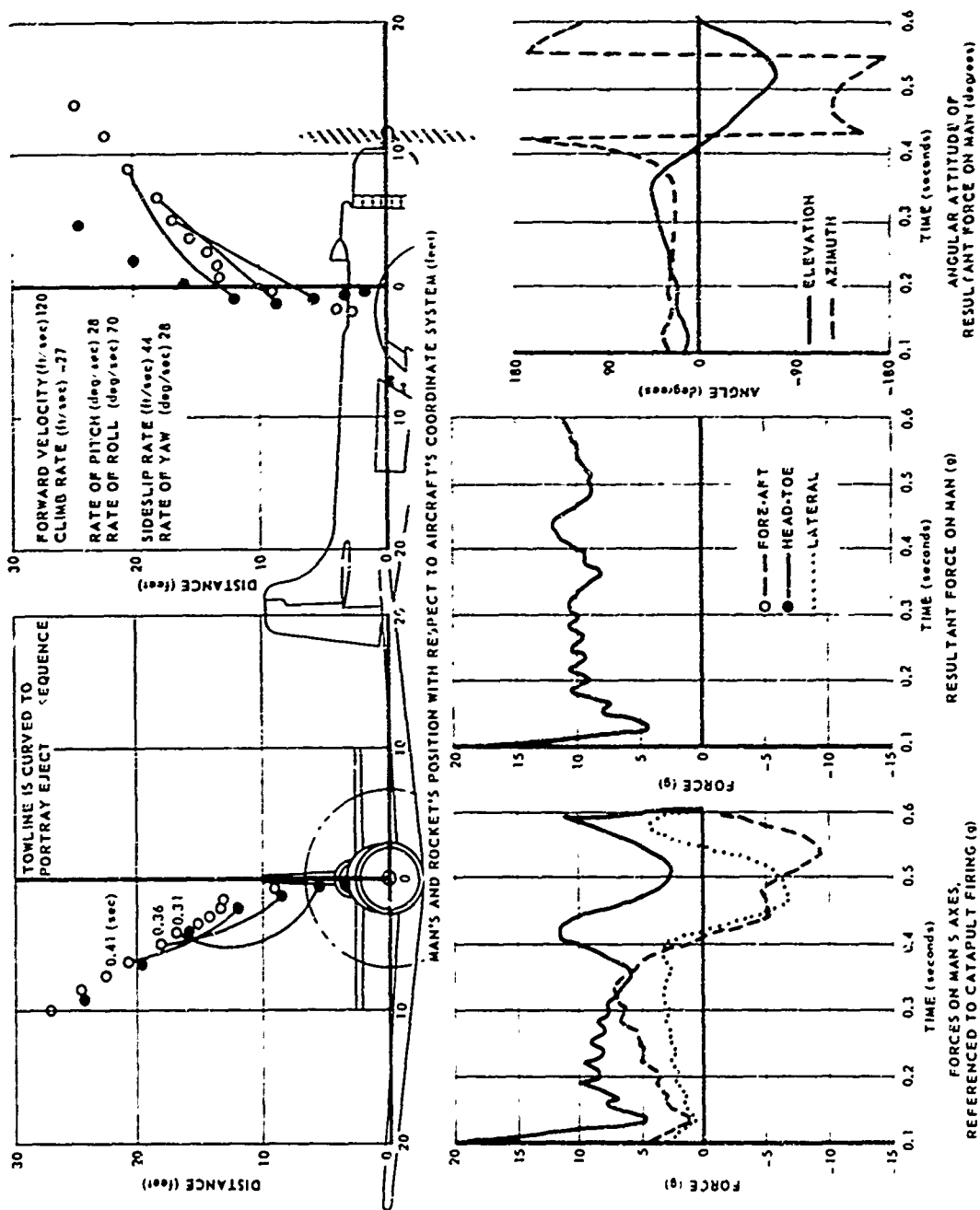Ejection Studies, Condition 13

Fig. 21   Simulation Results, Three-Dimensional Tractor Rocket
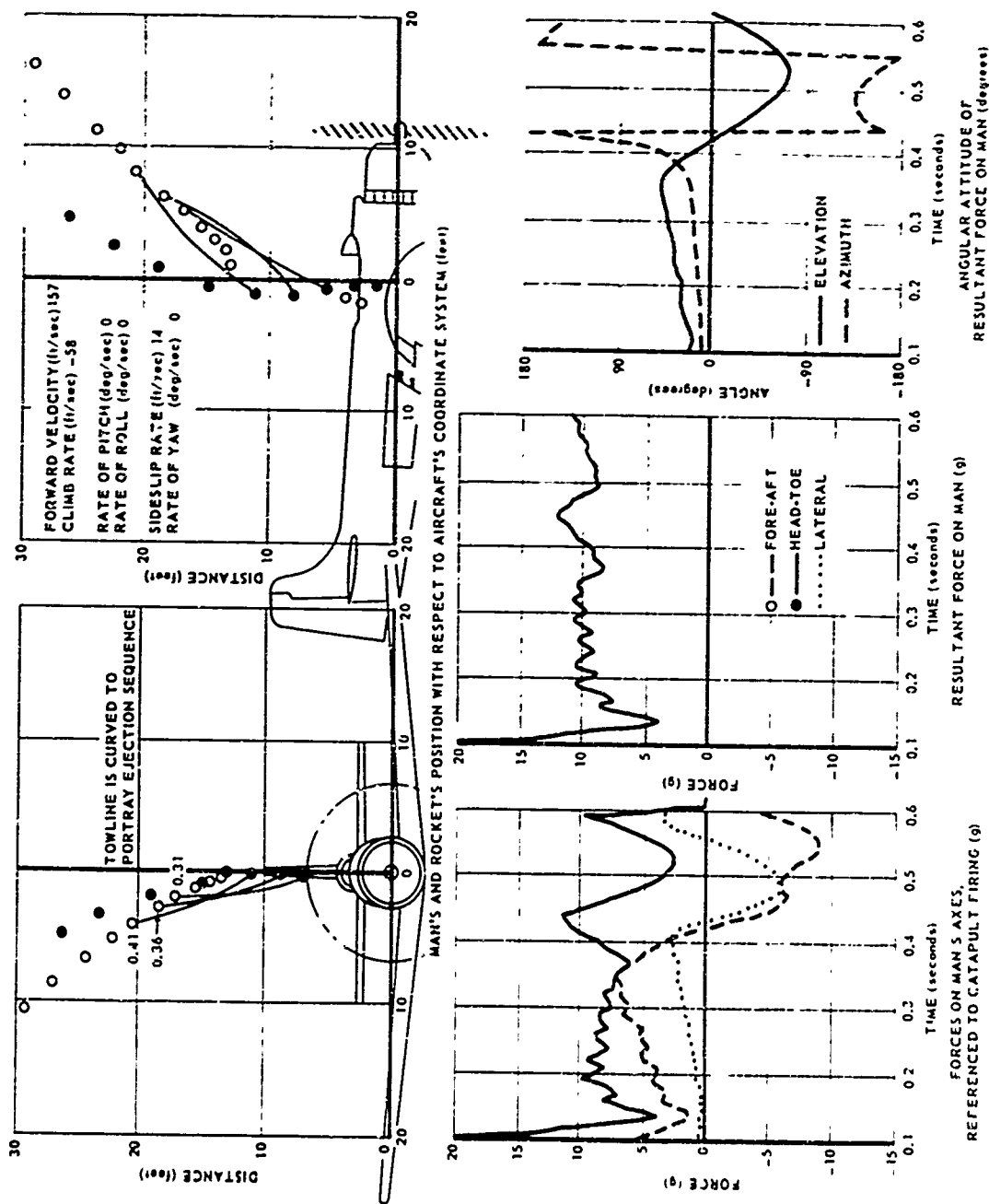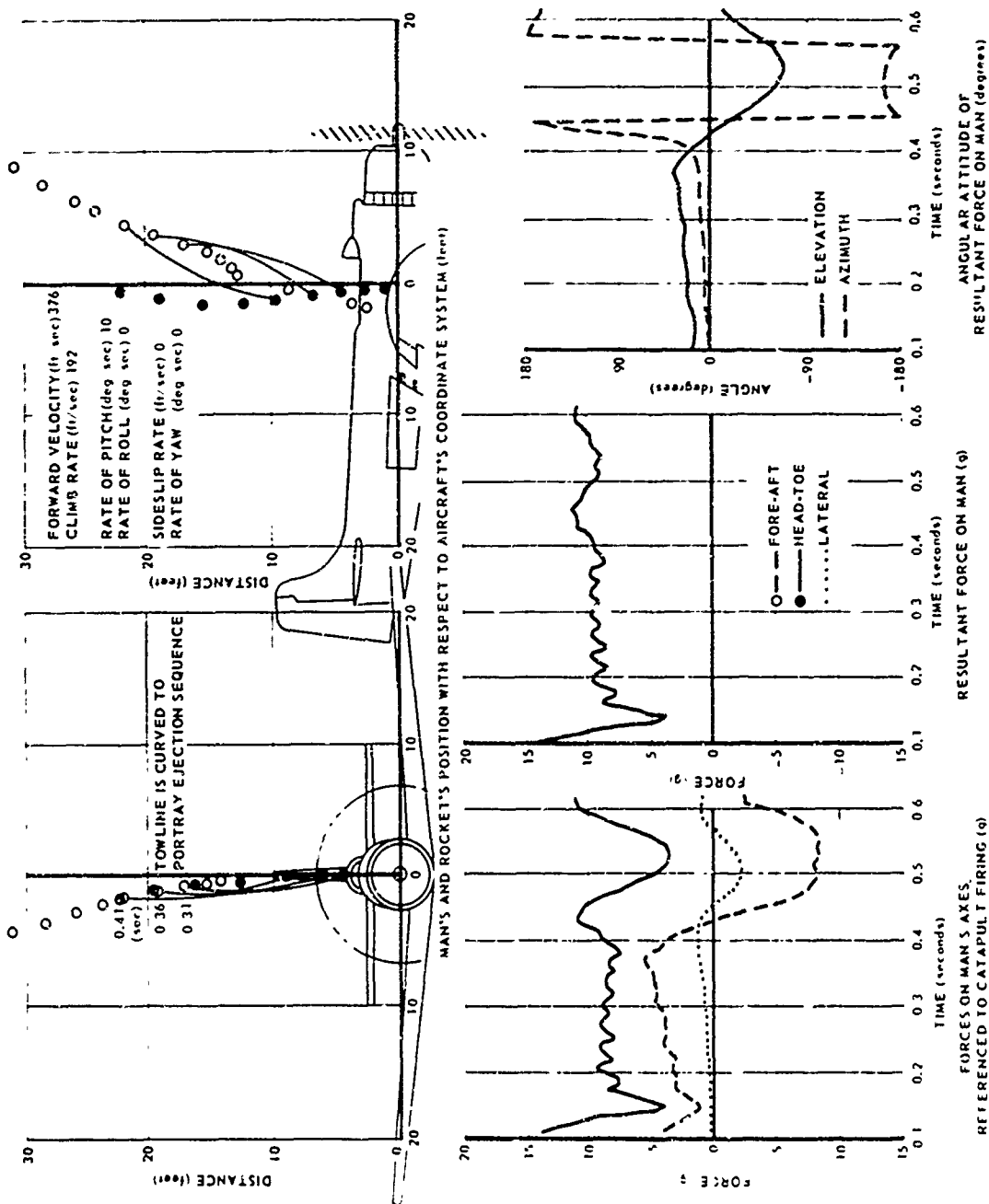Ejection Studies, Condition 14

Fig. 22 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 15

Fig. 23 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 16

Fig. 24   Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 17

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Fig. 25   Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 18

Fig. 26 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 19

Fig. 27 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 20

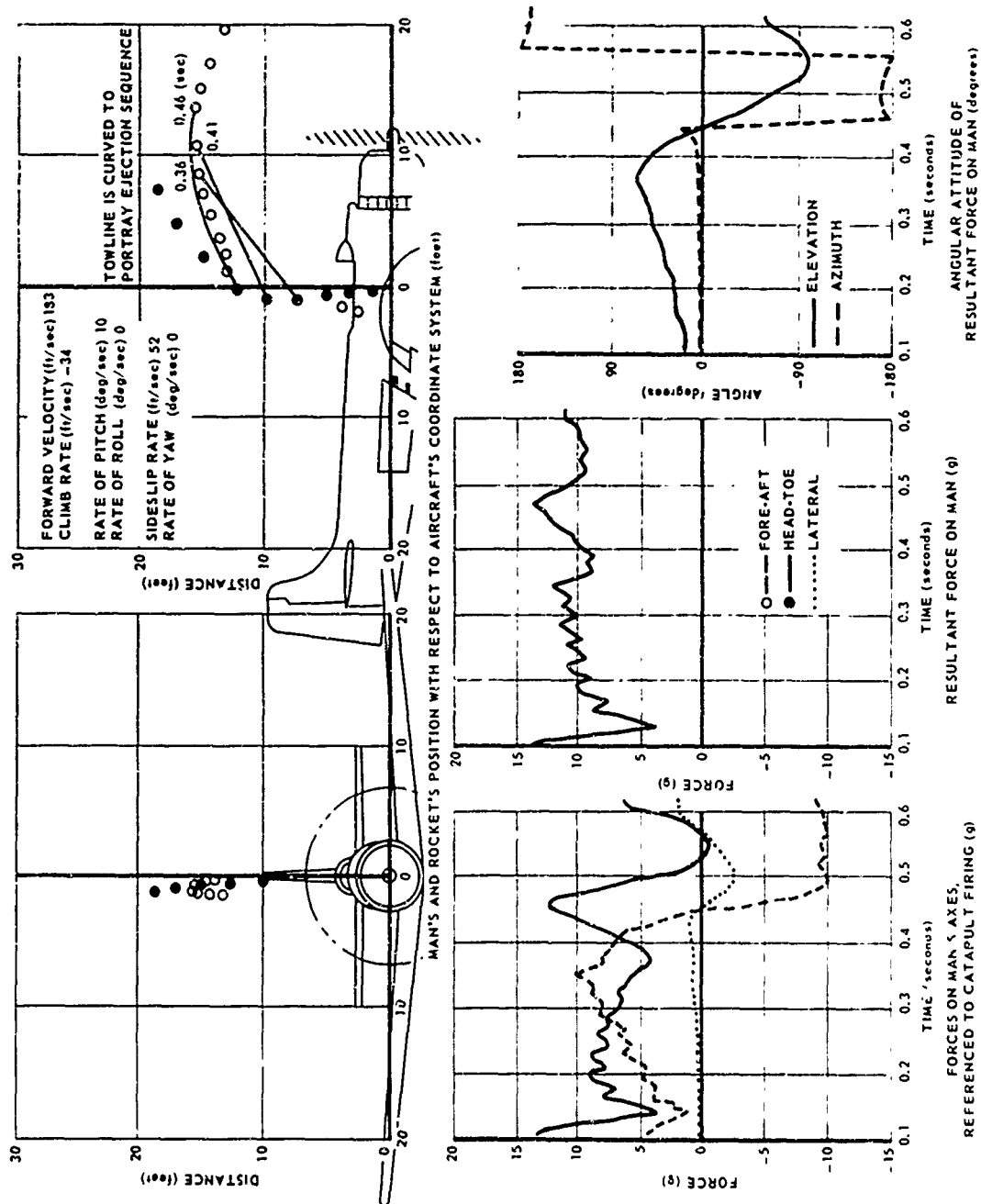Fig. 28 Simulation Results, Three-Dimensional Tractor Rocket Ejection Studies, Condition 21

Fig. 29 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 22

Fig. 30   Simulation Results, Three-Dimensional Tractor Rocket
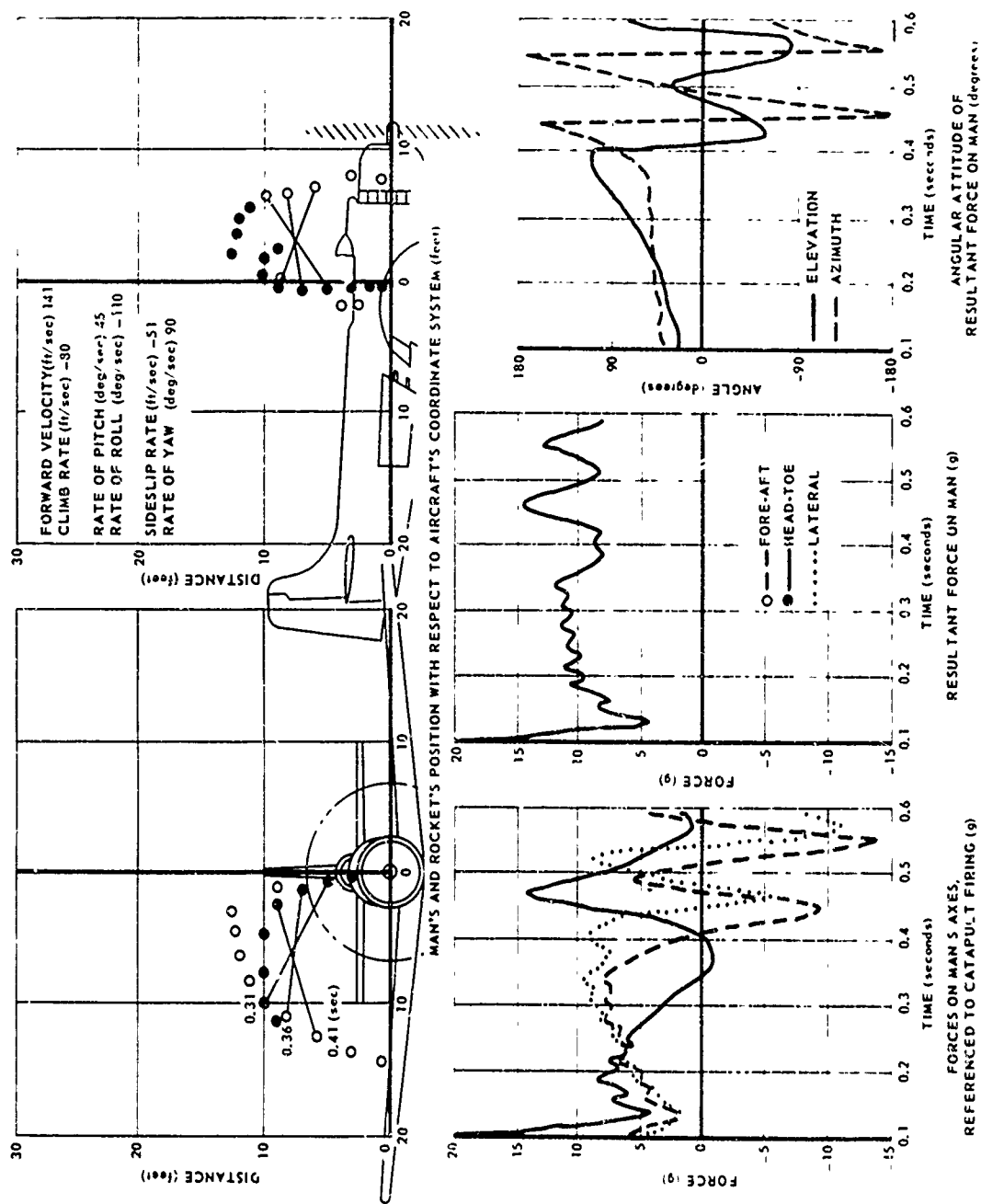Ejection Studies, Condition 23

Fig. 31 Simulation Results, Three-Dimensional Tractor Rocket
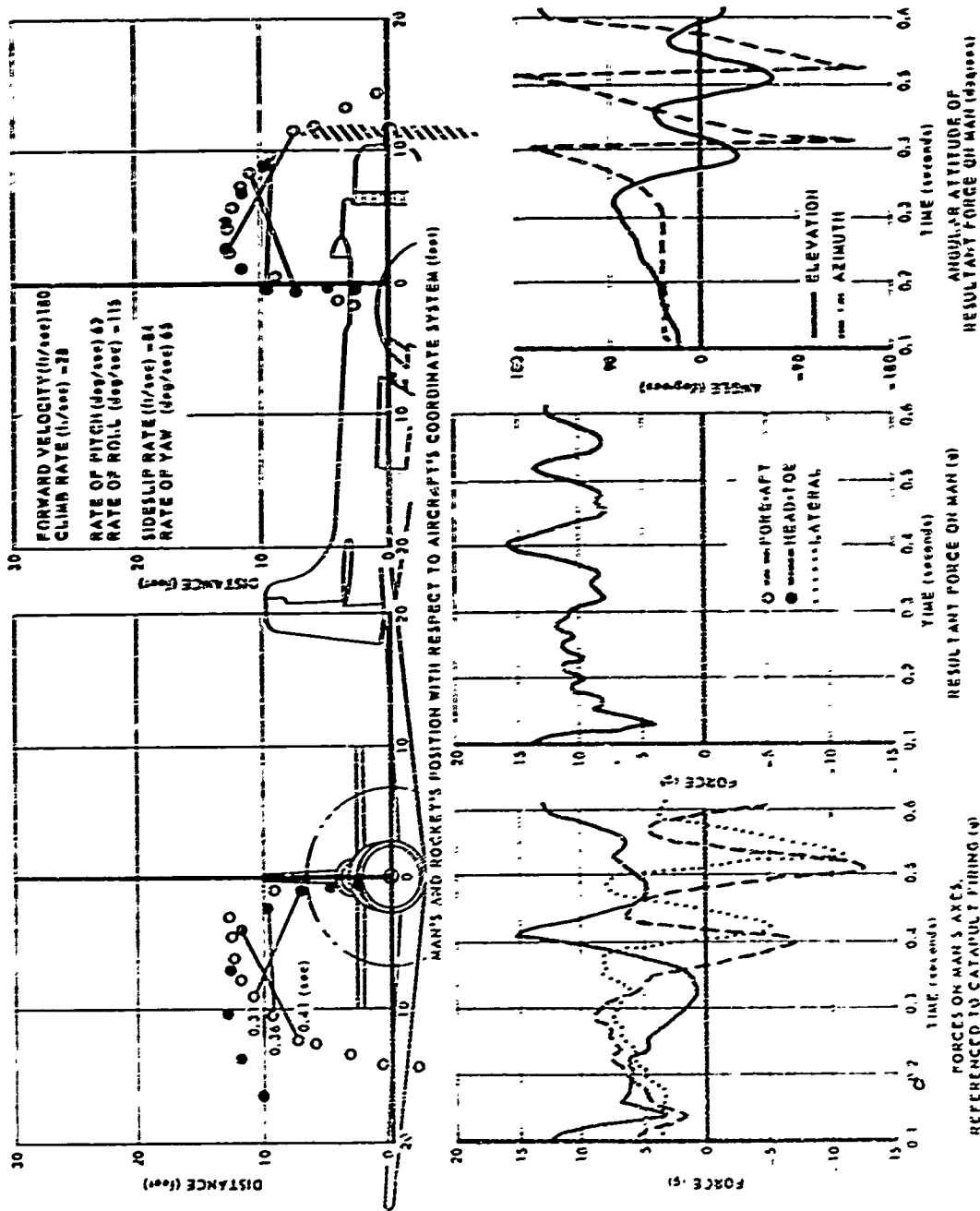Ejection Studies, Condition 24

Fig. 32 Simulation Results, Three-Dimensional Tractor Rocket
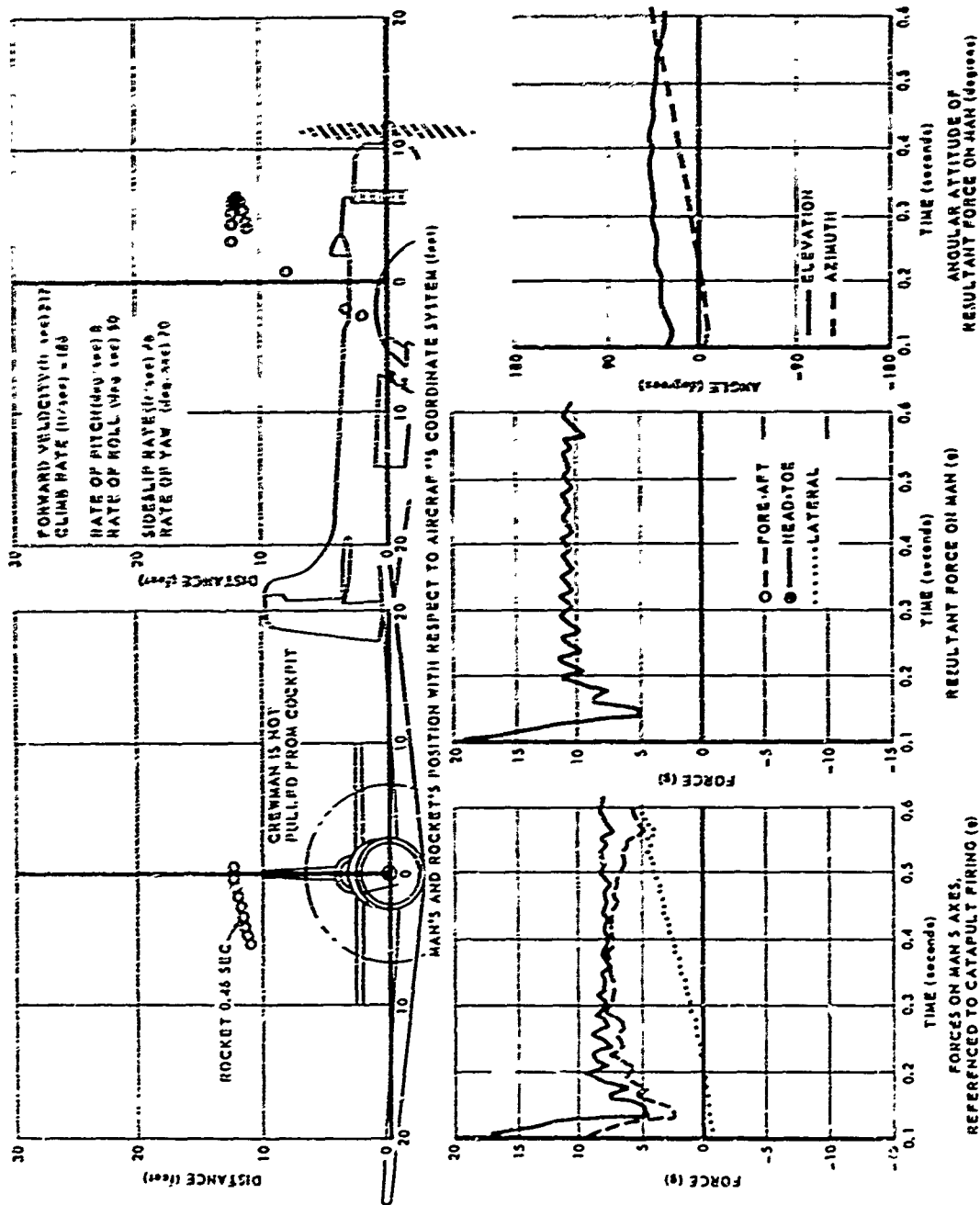Ejection Studies, Condition 25

Fig. 33   Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 1b (Rocket Catapulted 27°
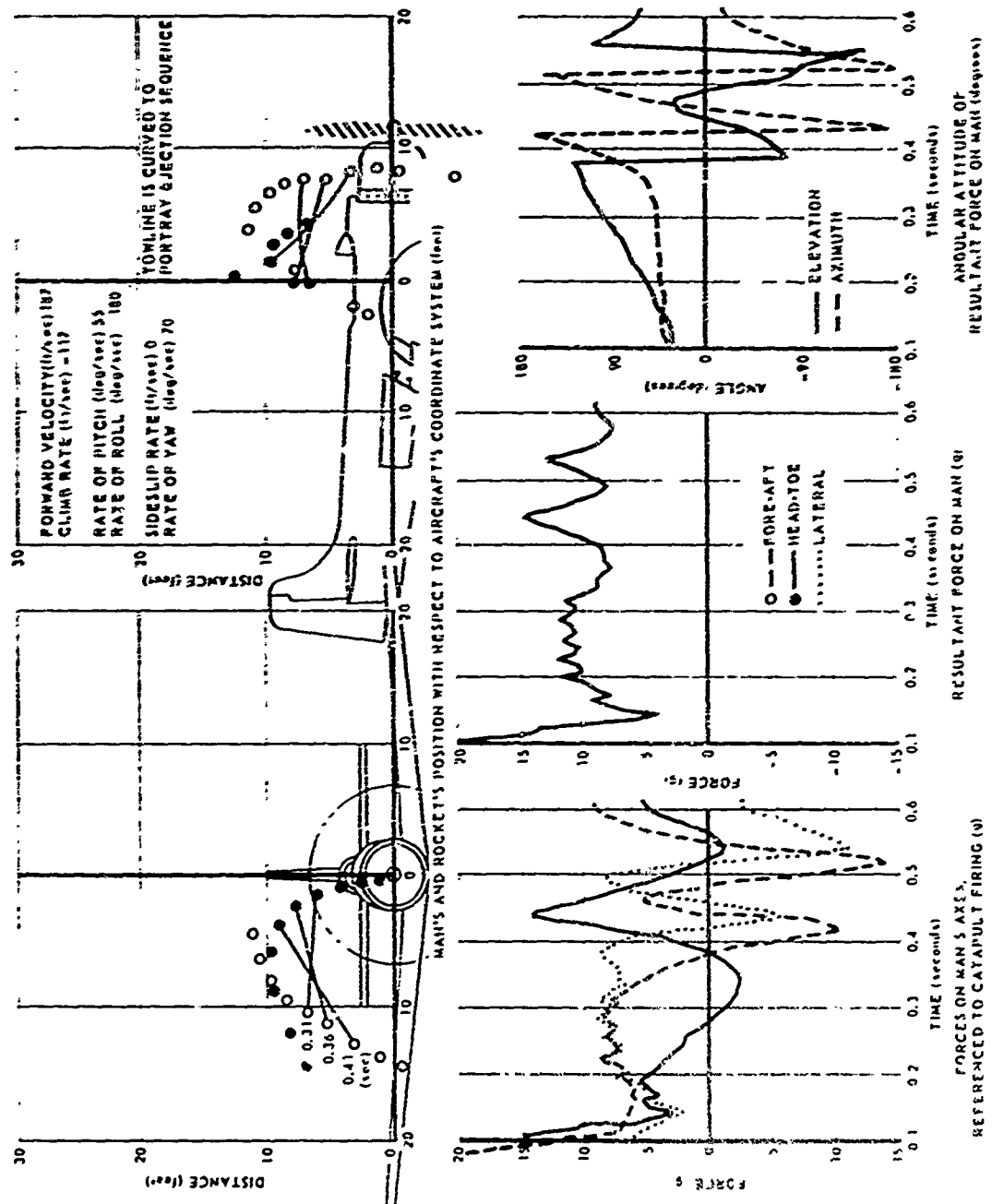ahead of Vertical)

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Fig. 34 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 2b (Rocket Catapulted 27°
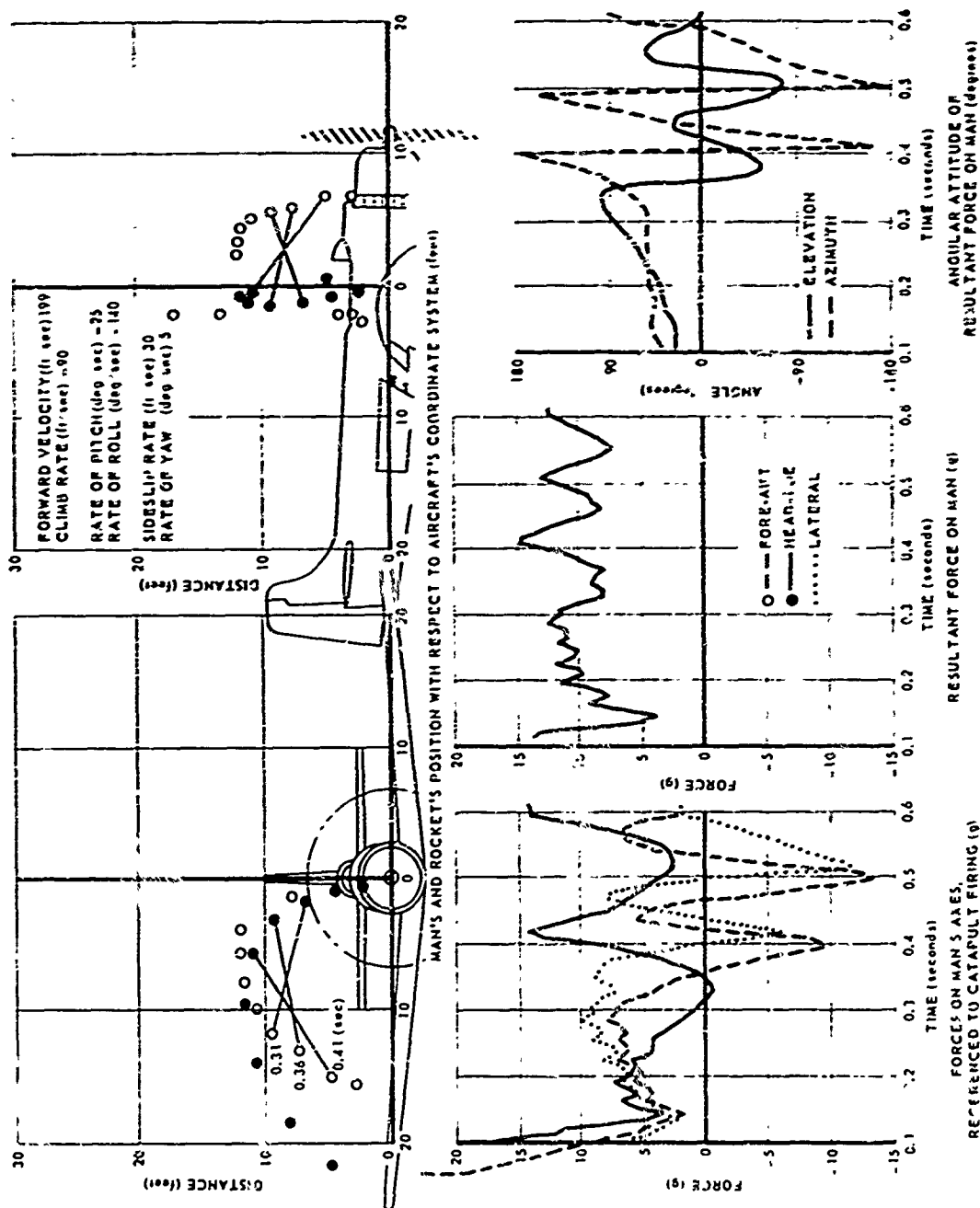ahead of Vertical)

Fig. 35 Simulation Results, Three-Dimensional Tractor Rocket Ejection Studies, Condition 3b (Rocket Catapulted 27° ahead of Vertical)

Fig. 36 Simulation Results, Three-Dimensional Tractor Rocket Ejection Studies, Condition 4b (Rocket Catapult at 7° ahead of Vertical)

Fig. 37 Simulation Results, Three-Dimensional Tractor Rocket
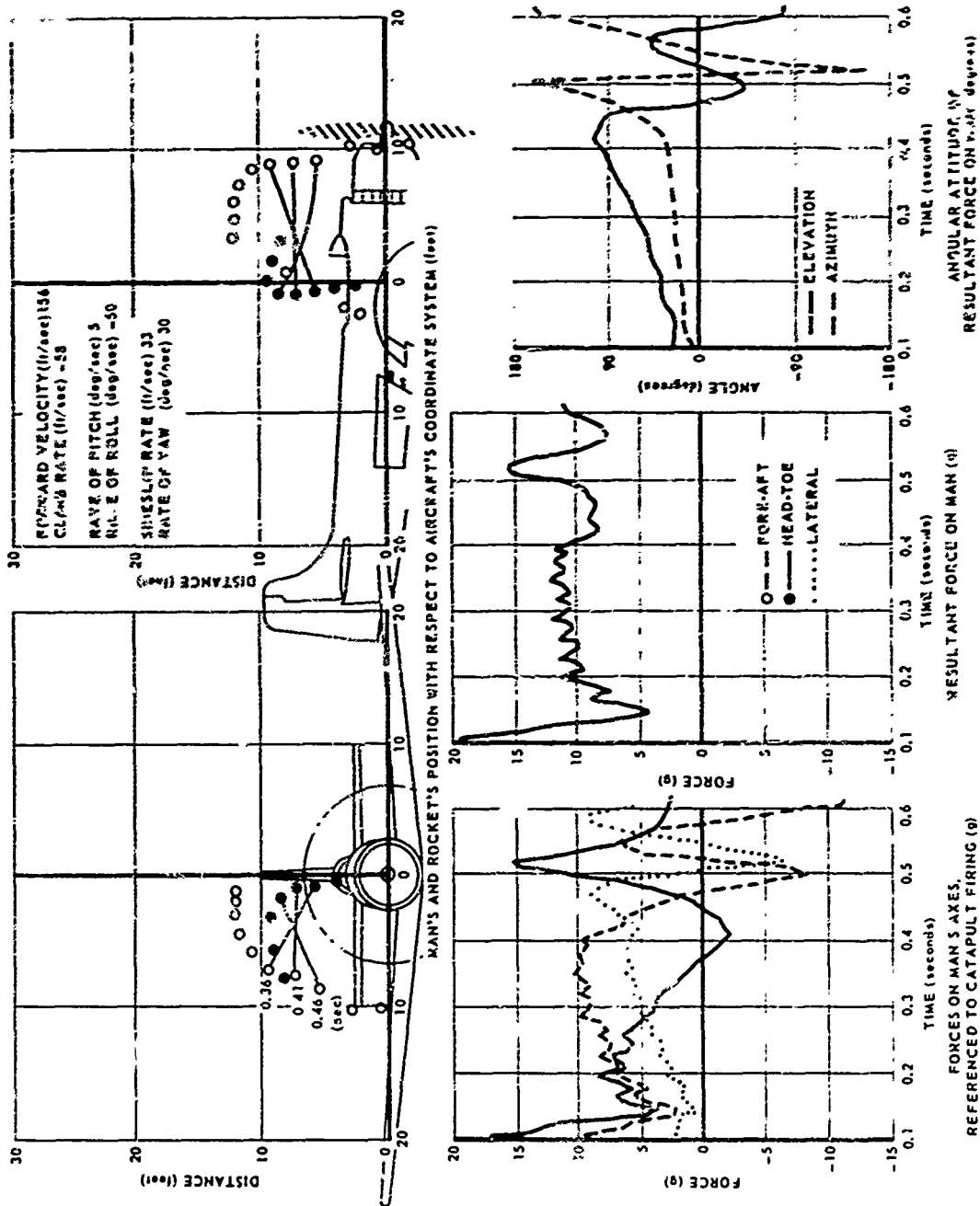Ejection Studies, Condition 5b (Rocket Catapulted 27°
ahead of Vertical)

Fig. 38 Simulation Results, Three-Dimensional Tractor Rocket Ejection Studies, Condition 8b (Rocket Catapulted 27° ahead of Vertical)
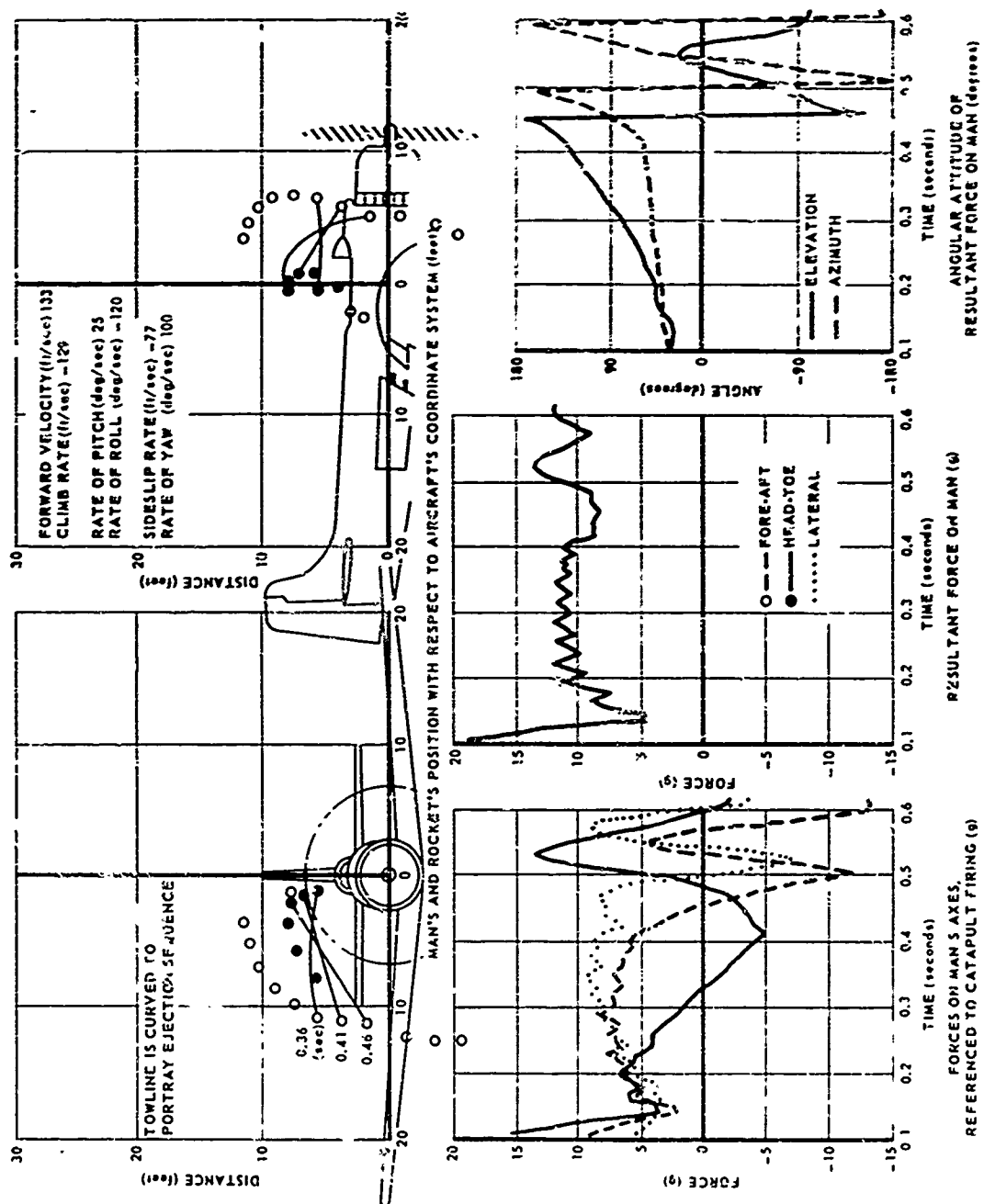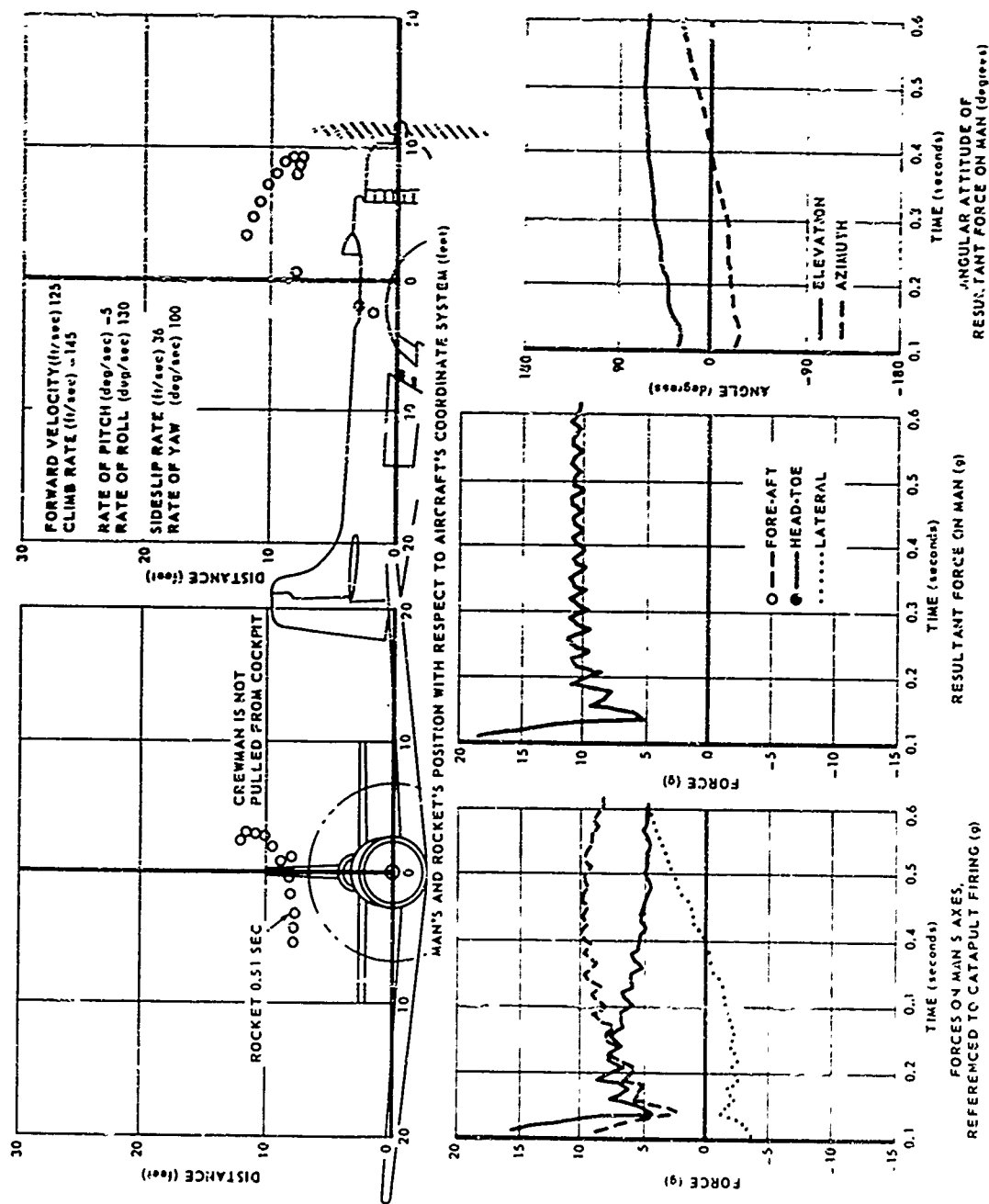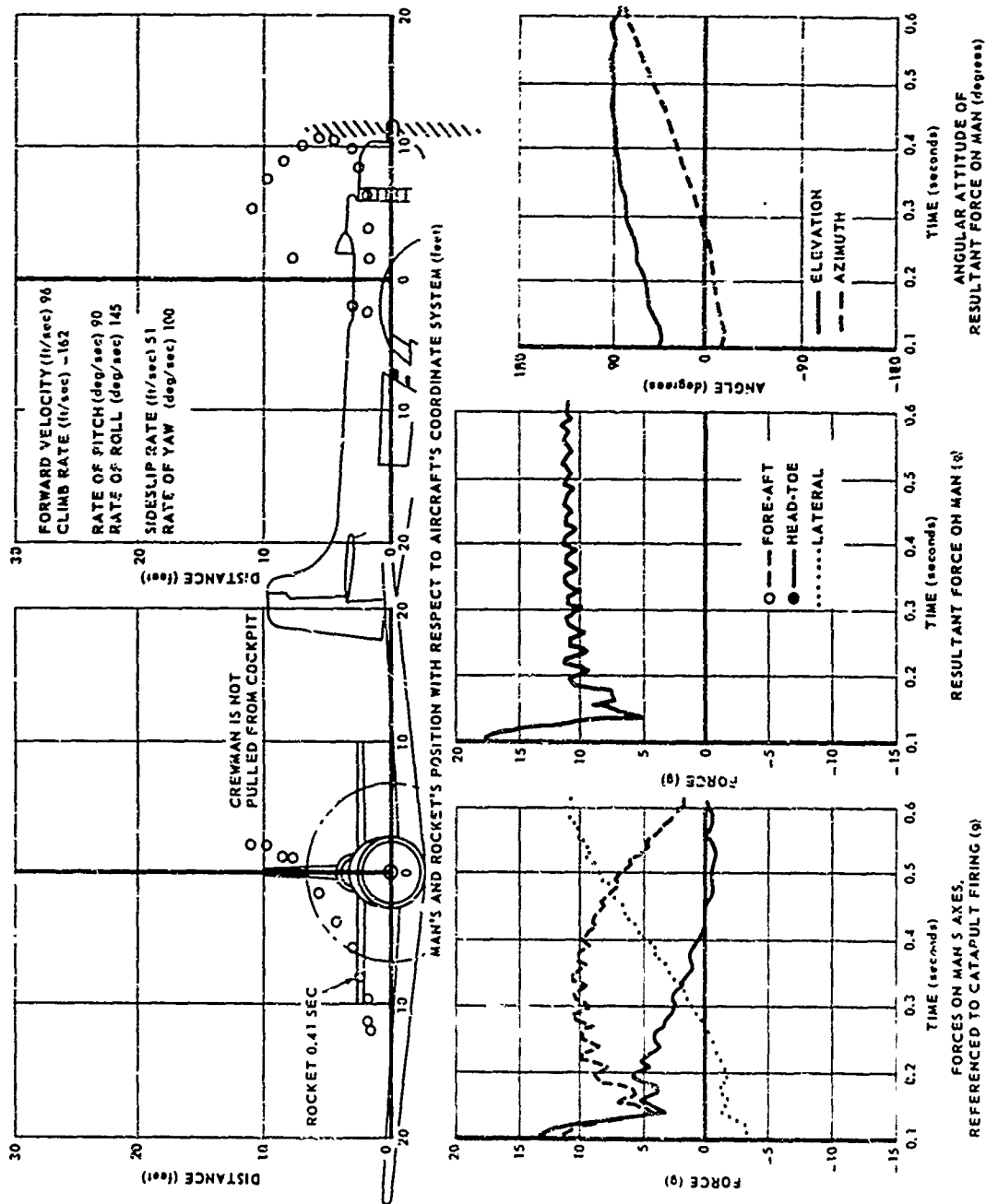
Fig. 39 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 9b (Rocket Catapulted 27°
ahead of Vertical)
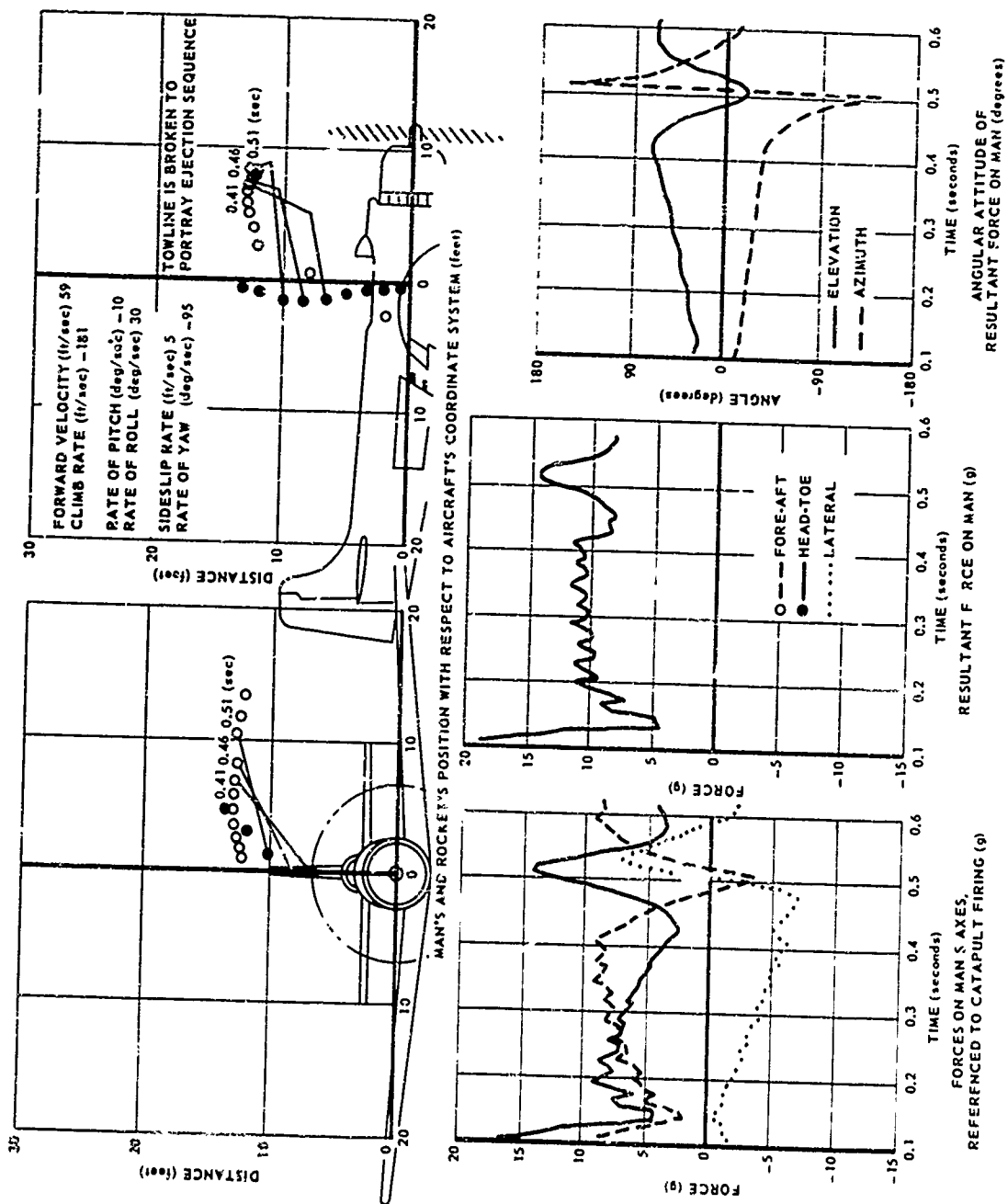
Fig. 40 Simulation Results, Three-Dimensional Tractor Rocket
Ejection Studies, Condition 10b (Rocket Catapult 27°
ahead of Vertical)

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13 ABSTRACT

      This report presents a six-degree-of-freedom digital simulation of an aircraft tractor rocket air crew escape system. The simulation described herein is a six-degree-of-freedom simulation in that each of the objects considered is free to translate linearly in three directions and rotate about these three linear axes. The simulation considers the motions of the four "objects" comprising the escape system: the airplane, the tractor rocket, the towline, and the crewman. The simulation begins at the instant the tractor rocket has been ejected from its catapult and terminates when the tractor rocket has burned out.

      The tractor rocket escape system was conceived by the Stanley Aircraft Corporation, for military aircraft which currently have no ejection systems for the air crew. (U)

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14.	KEY WORDS

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Six-Degree-of-Freedom Simulation
"Yankee" Escape System
Ejection Dynamics
Rocket Escape System
Stanley Aircraft Corporation